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Albert Reichmann

PRESIDENT W. S. E.—1913.

Journal of the Western Society of Engineers

VOL. XVIII

JANUARY, 1913

No. 1

ADDRESS OF RETIRING PRESIDENT, MR. W. C. ARMSTRONG

At Annual Dinner, January 8, 1913.

Members of the Western Society of Engineers and Guests:

One year ago, upon an occasion similar to this, when I arose tremblingly before you to express my appreciation of the honor conferred in electing me President of this organization, I committed an indiscretion which has since filled me with regret. One of my first utterances upon that occasion was intended to condone my faltering efforts and was like this: "Custom has not imposed upon the incoming President the duty of making an address. He is only expected to make his bow. But custom has laid that duty quite rigidly upon the retiring President. It is expected of him and he cannot get away from it." If I had not displayed an utter lack of foresight, I would not have spoken those words, or I would have qualified the statement by adding that this duty might be delegated to the Secretary, or to one of our recognized speech-makers. But on account of my failure to look ahead twelve months, I find myself now, to use the language of the street, "strictly up against it." Fortunately I did not mention any limit of length or standard of literary merit to which such an address should conform. This omission now offers the only loophole of escape, and I shall seize it with the same desperation with which we are told a drowning man grasps at a straw. As to brevity, I will follow, as nearly as practicable, the advice which Flannigan gave to Finnigan; and as to literary merit I will ask you to kindly forget it.

The Secretary has given you a report of the work of the past year. It showed that the Society is on a firm financial basis, and that we have a comfortable surplus in the treasury which has been growing slowly but steadily from year to year. While there has been no definite policy adopted as to the purpose to which this surplus is to be applied, I think it is the hope of every member of the Society that at some future day it may be applied in the purchase of a home of our own, or to the establishment of more permanent and commodious quarters.

While it is true that we are very comfortably housed in our present quarters, it must, nevertheless, be apparent to all that with

January, 1913

our steady increase in resident membership, and with our rapidly expanding library, the time will soon come when larger quarters will be necessary. When that time comes, and even before the necessity is really upon us, we should turn our attention to the question of a permanent home for the Society.

An organization is very much like an individual. Every one feels a certain pride in ownership; and we would feel the same pride in a Society home that belonged to us. Such a possession would give the Society a better standing and a greater prestige that would aid very materially in further growth and advancement. Such a consummation may be far in the future, but we are not prohibited from enjoying a dream of its realization.

The Society has had a substantial growth during the past year. Not as great as we had hoped, and not as great as we should have had, but enough to give us encouragement that results can be accomplished if we but work for them. There are large numbers of engineers in Chicago and throughout the West who should be members of the Western Society of Engineers, but whom we have not been able to reach. Some arguments should be advanced, or some measures adopted which would bring them in. They should either be convinced that membership in the Society would be a valuable professional asset, or their pride in Chicago as the greatest engineering center of the West should be appealed to, with the further appeal for their assistance in making the Western Society of Engineers, which is now the greatest engineering society in the West, truly representative of this great engineering center.

I would like to speak a word of praise for the general excellence of our *Journal* during the past year. This was the second year of the change from a bi-monthly to a monthly publication. The change has brought increased duties which have fallen most heavily upon the Publication Committee; and at times there have been doubts as to whether they would be able to procure the necessary material for four meetings per month, and to fill the *Journal* each month with matter of real value to the profession. Thus far they have been successful, but the success has only been attained by strenuous efforts.

I have often questioned whether the energies of our Society, and of other similar organizations, are not mis-directed,—whether we accomplish the greatest good to the greatest number by our intense efforts to extend the scope of technical discussion and produce a larger volume of engineering literature, simply scattering it broadcast over the world, with practically no systematized effort to abstract, summarize, classify and index this literature for the benefit of the busy man.

We have so many technical societies,—so many others, generally termed trade societies, semi-technical in character, besides our clubs for professional men and those engaged in allied lines of business,—that very few who labor under the pressure of modern

industrial life can give more than passing attention to their work. And not only have technical and professional societies multiplied to such vast extent, but the publication of technical journals has increased so largely that the busy man finds scarcely time to do more than turn their pages and read the titles. It seems to me, therefore, that it is not more literature that we need, but a better classification of what we have. We have a surfeit of literature, but a dearth of concise classification. I believe it is within the province of this Society, probably in conjunction with other similar organizations, to supplement the present line of work with some undertaking of this kind, which should be more extensive and comprehensive than anything yet undertaken by any technical society or technical journal, and which would redound greatly to the benefit of busy professional men.

Some of our technical societies have from time to time published indices to their own publications. Many of our technical journals have done the same; and one has published regularly an index of a much broader character. One society in particular, devoted to railway engineering exclusively, has directed practically its entire efforts to presenting its work in concise form for practical use. But very little of this work, done by societies or technical journals devoted to general engineering, has been comprehensive enough to satisfy the needs of the busy man of to-day.

I believe it will be necessary for our Society to inaugurate some work of this kind if it would confer upon its membership the greatest possible benefits. There has been a decided falling off in the average attendance at our meetings, which indicates that there is a decrease of interest in the reading and discussion of professional papers; and some policy must be adopted to maintain an active interest in the work of the Society and attract those whom we want to interest in our work.

I have no definite plan to offer for carrying into effect the work here suggested, even if it should be deemed wise to undertake it. I simply offer the thought as a possible line of action to be considered by those whose duty it may be in the future to shape the destiny of this Society and bring it up to the full measure of its usefulness.

The Constitution provides that the President shall, at the Annual Meeting, announce the result of the election of officers for the ensuing year. Our recent election has resulted as follows:

President—Mr. Albert Reichmann.

First Vice-President—Mr. A. Bement.

Second Vice-President—Mr. B. E. Grant.

Third Vice-President—Prof. J. F. Hayford.

Treasurer—Mr. C. R. Dart.

Trustee for three years—Mr. F. E. Davidson.

With this duty performed, my swan-song is ended. It only remains for me to introduce the new President, to cast my mantle upon his shoulders, and then retire to that realm of departed glory, from whose bourn there is no return.

For seven years the treasury of this Society has been guarded by one who has never faltered in his loyalty. He has protected its coffers with a watchful eye and a faithful heart. He has cautioned us when economy and conservatism were essential to our financial success. So conscientiously has his duties been discharged and so clearly was he entitled to recognition, that when his name was proposed for the presidency, no other aspirant had the temerity to oppose him. "Well done thou good and faithful servant; enter into thy reward," is the greeting with which we hail him. With full confidence that the interests of the Society will be most efficiently served, I take pleasure in introducing our President, Mr. Albert Reichmann.

ADDRESS OF PRESIDENT-ELECT, MR. ALBERT REICHMANN

At Annual Dinner, January 8, 1913.

Members of the Western Society of Engineers and Guests:

As you doubtless know, it is the custom for the retiring President to make the address of the evening and it is quite proper that it should be so, inasmuch as he knew what was ahead of him and had a full year's time in which to prepare it. In addition to this, he has acquired ample practice in speaking during his term of office. The incoming President has had only a few days in which to prepare his address and as these are almost the shortest days of the year, he is placed at a decided disadvantage.

I wish to thank you for the confidence which you have shown in electing me your President, as it is an honor, the equal of which is afforded to few men. In accepting this office, I do so feeling very keenly the responsibility which rests upon me, and can only say that I will faithfully endeavor to serve the best interests of the Society.

There is just one subject upon which I would like to touch for a few moments. The engineering profession, as such, has in later years become much broader. Since the work of the artisan became more highly specialized, as industry became more and more centralized, the planning of the work is being done more completely, and every minute detail of the construction is being thoroughly developed. The direction of the execution of the work is also becoming more and more extensive. Thus the field of the engineer is constantly broadening. But this is not without its pitfalls. It naturally creates two classes of engineers,—those who look after the general planning of the work and those who look after the de-

tails. It is very important that the engineer, after he has mastered the details, should study his work from a broader aspect.

Strange as it may seem, in some respects the status of the engineer has not, as yet, been as fully recognized in the eyes of the law as that of the physician, lawyer, and architect. If, for instance, the engineer should design a building in the State of Illinois, though a purely engineering piece of work he cannot secure a building permit for the execution of the same without first having a licensed architect put his stamp on the plans. This not only works a great hardship upon the engineer but also does him a great injustice, as in a measure the architect must receive a certain amount of credit for the work of the engineer. We are naturally inclined to ask ourselves why such a state of affairs exists, but a moment's thought will make it quite evident. It is not that anybody wishes to do the engineer an injustice; it is merely because the engineers have not been looking after their own interests as carefully as they should have.

The engineer is sometimes criticized for not being a good business man. If this be true to any extent, it is not because he lacks ability but because he has not asserted himself and demanded his rights. The mere act of the architect putting his stamp on the engineer's plans, places the architect in a superior position in the eyes of the world as a business man.

There is now a bill before the State Legislature for re-codifying the State building laws. A committee has been appointed, on which the Western Society of Engineers is represented, in order that the engineers be given proper recognition in the framing of these new laws. A committee can accomplish a great deal but not everything. It must have the support of the members of the Society, and in order that the engineers may get the full benefit of that support they must not only work individually to assist the committee, but they should also belong to the Western Society of Engineers, for there are times when numbers count. Some of you may think that this is of no interest to you individually, but whatever is of interest to any member of the profession is of interest to all. Therefore, we can readily see that we as a body can be of great assistance to the engineering profession.

The Western Society of Engineers occupies an enviable position owing to its location in one of the greatest industrial and commercial centers, not only of the United States but of the whole world, and has, therefore, a large percentage of its members resident. As an engineering society it is broader in its scope than the national societies, its membership being composed of every branch of the engineering profession. Under the proper guidance and leadership it must hold a leading position among the engineering societies of the world. Therefore, it behooves us, as engineers of this community, to foster and further the interests of this Society.

PANAMA TRAFFIC AND TOLLS

UNWISDOM OF TOLL EXEMPTION FOR COASTWISE SHIPPING.

EMORY R. JOHNSON.*

Presented at the Annual Meeting, January 8, 1913.

It is indeed a pleasure and a privilege to meet with this Society, composed of men who do things. During the past fifteen years it has been my good fortune to be associated, from time to time, with engineers—army and civilian—entrusted with the solution of important questions and execution of large works. Association with such men as Alfred Noble, General Haines, General Bixby, the late George S. Morison, and acquaintance with men of achievement like Colonel Goethals and his associates now composing the present Isthmian Canal Commission, would, I am sure, be highly valued by every economist.

I have some diffidence in addressing, or presuming to address, men of your technical attainments. Indeed, I feel that I should be at the foot of the class rather than apparently next to the head.

The subject that has been assigned to me is Panama Traffic and Tolls, and I wish to approach this commercial discussion from the point of view of the provision in Section 5 of the Canal Act, which exempts from the payment of tolls the American coastwise shipping.

The provision of the Panama Canal Act, exempting American coastwise shipping from the payment of tolls, raises two questions;—our rights under the treaty of 1901 with Great Britain to adopt such a policy; and the economic wisdom or unwisdom of such a policy, irrespective of the provisions of the Hay-Pauncefote treaty.

Two views are held as to the meaning of the treaty. One view is that the treaty means what it seems to say, *i. e.*, that the principle of the neutralization of the canal, as broadly established by Article VIII of the Clayton-Bulwer treaty of 1850, has been incorporated without impairment in the treaty of 1901, and that we have promised to treat our ships using the canal the same as we treat British ships. The other view is that the Hay-Pauncefote treaty merely requires the United States to accord equal treatment to the vessels of all other nations.

I do not wish to discuss the possible meanings that may be given to the phraseology used in the Hay-Pauncefote treaty. I am, however, especially pleased by the stand taken by President Taft that the meaning of the treaty is a question to be arbitrated. Indeed, it seems certain that we must eventually either repeal the toll exemption clause of the Canal Act of August 24, 1912, or ar-

*Special Commissioner on Traffic and Tolls.

bitrate the question of the exemption of American ships from the payment of Panama tolls.

If the law stands as it is and tolls are collected on ships under the British flag, and not on ships under our flag, Great Britain will doubtless insist upon damages; and if the demand is ignored by the United States, Great Britain may be expected to seek to cause our shipping or commerce to suffer by the amount of the damages she claims. Retaliatory measures on the part of Great Britain would certainly cause us to seek a settlement of the questions at issue. Of course, the settlement would be by arbitration, because it is inconceivable that Great Britain and the United States should be drawn into war over a difference of interpretation of the meaning of a treaty affecting the treatment of shipping.

As between arbitration of the question of the exemption of American coastwise shipping from the payment of Panama tolls, and the repeal of the toll exemption clause of the Canal Act, the latter course is the wiser one to pursue. If we arbitrate and lose, we must return all the tolls that have been collected and henceforth either charge no tolls or collect the same tolls on all vessels using the canal. If we arbitrate and win, we will but have established our right to pursue an unwise policy—a policy that is indefensible whatever may be our rights under the Hay-Pauncefote treaty.

The policy of the United States, with reference to the exemption of American coastwise ships from the payment of Panama tolls, ought not to be decided with reference to the rights of the United States under the treaty. The questions to be considered are:

Do the coastwise carriers need to be given a subsidy of nearly \$20,000,000 during the next ten years?

Will the general public—shippers and consumers—be benefited by this subsidy, *i. e.*, will freight rates by coastwise lines or by rail lines be lower?

Is this the best method of using public funds to aid the merchant marine?

Are tolls upon all ships needed to make the canal self-supporting and not a burden upon the general tax-payers?

(1) It must be evident to every impartial student of the question that it is not necessary to relieve coastwise shipping of canal tolls as long as foreign-built ships are not allowed to engage in the domestic commerce of the United States. American ship owners have a monopoly of the coastwise trade. In 1911 there were 3,537,750 tons of American ships enrolled for the domestic trade on the Atlantic-Gulf and Pacific seaboard. The increase during the preceding decade had been 38%. There is thus a relatively large and healthily increasing tonnage of coastwise shipping; and the opening of the Panama Canal will undoubtedly bring about a large addition to the coastwise fleet. Our coastwise marine is now given sufficient aid and protection by our navigation laws.

(2) The sentiment in Congress and elsewhere in favor of relieving the coastwise shipping from the payment of Panama tolls seems to be due largely to the belief that if tolls are collected from the steamship lines, the freight rates which they charge and the rates of the transcontinental railroads will be higher by the amount of the tolls, and the public will thus pay more in added freight rates than it will gain in tolls received. This argument, however, assumes an improbable adjustment of rail and water rates. The rates of the steamship lines and the railroads will not be higher if Panama tolls are collected from the coastwise lines.

Those who contend that the traffic carried by rail between the eastern and western parts of the United States will be charged rates increased by the rate of canal tolls, assume that the rail charges must be and will be controlled by the coast-to-coast water rates, and that the schedules of railroad rates will be fixed at such differentials above the water rates as the railroads can charge and secure traffic in competition with the rival water lines. In order to bring about this adjustment of rail and water rates there must be, first, active rate controlling competition among the water lines, and, second, it must be the policy of the railroads to fix rates so as to compete actively with the carriers by water for practically all traffic moving between the two seaboard. Will these conditions exist?

It is the practice of steamship lines, when operating between common termini, to adjust services and rates by "conferences." The informal organizations or conferences of steamship companies are able to regulate competition, and to prevent rates from being forced by competition to the level below which they could not be forced without making the business unprofitable. When several steamship lines operate over established routes and serve the same sections, they are able, by agreements and understandings with each other, so to limit competition as to make their services and rates at least partially monopolistic. Unless prevented by effective government regulation, steamship companies will, like railroad companies, steadily increase the monopolistic character of their service.

That is a strong statement, which may not meet with your immediate approval. The general supposition is that the railroads have ceased to compete with each other in rate making; they do in service. The theory is still held by many very intelligent people that competition is still controlling upon the water. The study that I have given (although I admit that it is somewhat casual) during the past ten or fifteen years, to the relation of steamship companies to each other, convinces me, at least, that the relations of steamship lines operating between fixed termini and serving common sections are essentially the same as the relation of railroads to each other. As you know, the house committee on merchant marine and fisheries a year ago was authorized by the House of Representatives to make a thorough investigation of the shipping business, the relation

of steamship companies to each other and to the railroads, to specially analyze rates,—the whole subject of the shipping business. That committee, as it happened, employed as its traffic expert a colleague of mine, Professor S. S. Huebner, a Manitowoc, Wisconsin, boy, by the way. I have kept somewhat in touch with the investigation as it has proceeded, and the information possessed by the committee shows conclusively that all steamship lines operating over fixed routes between established termini are members of conferences; that the rates are common for common service, and that the ordinary practice of competition, the former practice of competition, which is ordinarily supposed to prevail, no longer exists to any considerable extent.

If those be the facts, and they are the facts, and the investigations and hearing and report of the merchant marine committee will establish the facts beyond question, there is only one conclusion to draw, and that is the one that I have just drawn, that unless prevented by effective government regulation, steamship companies will, like railroad companies, steadily increase the monopolistic character of their services. We must face, when we are intelligent enough to do so, the question of the regulation of transportation by water and apply to that problem the same principles that we are successfully applying to the regulation of transportation by land.

If this analysis of the relation of steamship companies with each other be correct, it follows that the rates charged by steamship lines between the two seaboard of the United States will be, or will tend to be, not the lowest rates at which traffic can be profitably handled, but rates as high as the interested steamship lines think the rates can be put without limiting the growth of traffic or without losing tonnage to the railroad lines. Steamship companies, like railroad companies, will tend to charge what the traffic will bear, and steamship traffic will bear such rates as shippers will pay to have their goods transported by water instead of by rail. If this be true, the tendency will be for carriers by water to adjust their charges with reference to the schedules of railroad rates. In so far as this practice of rate making prevails, it will be impossible for the carriers by water to add the canal tolls to their rates. Whether there be canal tolls or not, rates by water carriers will be such as the traffic will bear; the upper limit of what traffic by water will bear will be the lower limit to which rates are brought by the railroad; and the tolls will be paid by the owners of the steamship line instead of by the shippers in additional rates.

This argument is theoretical. I might just as well have made it a concrete statement instead of a theoretical argument. The manager of the largest American coast-to-coast steamship company in operation today incidentally, in a conversation a few months ago, said to me, "It has always been my theory that the ship rather than

the shipper pays the tolls," which is the theory which I have just advanced.

The President of the United States Steel Corporation, in answer to the question which was put to him, said, "The rates will not be affected by charging tolls upon coastwise shipping."

The Vice-president of the Pacific Mail Steamship Company, who is a practical railroad man as well as a practical steamship man, in his testimony before the Senate committee and in conversation with me personally, has said more than once that the tolls on shipping will be an operating expense to be borne by the carrier.

These three statements by technical men, speaking without any reference to each other and without any regard to any theory that I have advanced, bear out the correctness of the theoretical conclusions I have just presented.

What I have said refers to the traffic of steamship lines. Investigations that have been made into Panama canal traffic show that at present over four-fifths of the traffic carried between our two seaboard is handled by lines and not by individual chartered vessels. The business of the future will be mainly line traffic, and only to a small extent will it be traffic handled in individual chartered vessels owned by the producer or shipper.

In the case of chartered vessels, however, the shipper, not the owner of the vessels, must bear the burden of the canal tolls. Charter rates will necessarily be increased by the amount of the canal tolls; and, in so far as the railroads compete with the chartered vessel for lumber and similar traffic, the canal tolls will be of advantage to railroads. That is what so many people are afraid of, that the canal tolls will help out the railroads. This advantage, however, will be more theoretical than real. It is not probable that the railroads can, in any event, compete with the carrier by water for bulk cargoes of lumber, coal, and similar products. The railroads will be obliged to allow that traffic to move by water. They will not run the risk of depressing their general schedule of commodity and class rates for the purpose of preventing chartered vessels from securing traffic that can be handled between the two seaboard of the United States for \$5.00 or \$6.00 per ton. The railroads will let that traffic go to the water carriers, and the water carriers, not the railroads, will fix the rate on that bulky traffic which moves by water.

It will be the policy of the railroads to allow a portion of the traffic that might be held to the rails to be shipped coastwise through the canal, and to maintain rates upon the traffic which can be readily prevented from taking the canal route. It is probable that the railroads will adopt the general policy of surrendering, without serious struggle, the minor portion of their traffic in order to maintain profitable charges upon the major share of their tonnage.

Investigations recently made and embodied in the Report upon Panama Canal Traffic and Tolls, submitted to the Secretary of War

in August, show that somewhat less than one-fifth of the traffic handled by the transcontinental railroads to the Pacific seaboard terminals originated in the territory east of Pittsburgh, and somewhat over four-fifths originated in the Pittsburgh territory and in the Mississippi Valley. Nearly half of the through tonnage originated west of Pittsburgh. The competition of the canal with the railroads will be governing and controlling, speaking of westbound traffic, for that traffic which originates east of the Pittsburgh territory, and which constitutes somewhat less than one-fifth of the through transcontinental westbound tonnage. In all probability, fully one-half of that one-fifth is traffic that is certain to move by rail. It is not the kind of traffic that will leave the rails for the more devious, though cheaper, water route. Thus, at best, the railroads may be said to have at stake something like one-tenth of their traffic, which they will probably lose on the westbound transcontinental business if they maintain rates on the nine-tenths of the traffic which they will not lose by maintaining rates. Such being the situation, it is but rational to assume that it will be more profitable for railroads to maintain their general schedule of rates and thus make sure of profits upon nine-tenths of their business, without seeking to lower the rates on nine-tenths of their traffic in order to hold against the water lines a part of the one-tenth of their business.

The fact that the railroads now have petitions before the Interstate Commerce Commission, asking permission to raise their westbound transcontinental rates, is evidence that they are not looking forward to a lower schedule of rates in the near future.

The effect of canal tolls upon rail and water rates, and the adjustment of the charges of coastwise and all-rail carriers handling traffic between the two seaboard of the United States may be summarized as follows:

Producers and consumers would not secure the major share of the benefits resulting from the remission of tolls upon coastwise shipping using the Panama canal. On the traffic handled by steamship lines between the two seaboard, rates will be but slightly affected by canal tolls. The coastwise traffic between our Atlantic and Pacific ports will consist mainly of general commodities and package freight handled by the established steamship lines. The rates charged by the steamship lines, being regulated by agreements among competing companies and being fixed with reference to what the traffic will bear, will presumably be as high as traffic conditions warrant, regardless of tolls. The several lines will have uniform and relatively stable schedules of charges, and the rates of the steamship lines will ordinarily be adjusted with reference to the stable schedule of commodity and class rates prevailing upon the transcontinental railroads and their rail connections. If canal tolls are charged, the operating expenses of the steamship companies will be increased by the amount of the tolls, and their net profits will be lessened by the same amount.

Charter traffic between the two seaboard of the United States will be limited to a few commodities handled as bulk cargoes by or for the exceptionally large shipper. Chartered vessels will not compete with the regular steamship lines to such an extent, nor in such a manner, as generally to regulate the rates charged by the steamship lines on the greater portion of their traffic.

The lobby that was maintained in Washington during the past session of Congress, to bring about the exemption of the coastwise shipping from the payment of tolls, represented, among others, the Northwest Coast lumber interests. At least two representatives of that industry appeared before the House and Senate committees in opposition to tolls upon coast line shipping. I can see how the Northwest lumbermen would prefer not to pay the tolls.

Those who are to pay the tolls know the difference between those who are to bear the tolls and those who are not to bear the tolls, and they wish to be freed from the burden.

(3) The exemption of American coastwise shipping from the payment of Panama tolls is a poor kind of subsidy to our merchant marine. The money will go to our shipping that needs no aid and not to our vessels that require assistance. If the United States is to adopt a ship subsidy policy, and I personally would not oppose it, the public funds should go where needed, and should be granted in such a manner as to be effective in building up our merchant marine engaged in the foreign trade in competition with ships under the flags of other countries. The experience of Japan, Germany, and even of Great Britain, shows that the only effective ship subsidies are those paid to strong lines operated over routes deemed important to the government granting the subsidy. To aid our merchant marine in such a way as to produce results, strong lines must be selected or created and given such support as they require to enable them to compete successfully with foreign steamship companies and grow stronger year by year; the government must concentrate its aid and strengthen the strong lines assisted. It has been suggested that it would be wise for the United States to pay back the Panama tolls collected from the owners of American ships engaged in our foreign trade through the Panama canal. Such a subsidy, however, would be so small and so thinly distributed as to be ineffective; moreover, the repayment to ship owners of the Panama tolls collected from them would invite similar action by other nations to overcome the effect of our action. Such a subsidy would be one suggesting retaliatory action.

This is not the occasion to discuss ship subsidies, but if we are to adopt that policy the exemption of ships using the Panama canal from the payment of tolls is not the way to subsidize our marine. We ought to have a strong, active American line from our west coast by way of Hawaii, Japan, and China to the Philippines. It would be desirable from the point of view of the development of our foreign trade to have an equally strong line out to Australia.

We ought to have a line from New York and gulf ports through the canal down to the west coast of South America, and we ought to have another vigorous line down the east coast of South America to Buenos Aires.

Apparently the only way to bring those lines into existence and keep them in a condition that will enable them effectively to compete with British and German lines, is to give them government support large enough to make them able to compete successfully and to grow stronger year by year.

(4) Are tolls from all vessels using the Panama canal necessary to make the canal commercially self-supporting, to prevent it from adding one more permanent load to the increasing burdens of the general taxpayers?

The annual revenue ultimately required to make the canal commercially self-supporting would be about \$19,250,000. It is estimated that the operating and maintenance expenses will amount to \$3,500,000 yearly, and that \$500,000 will be required for sanitation and for the government of the zone. The interest on the cost of the canal, \$375,000,000, at 3% per annum, will amount to \$11,250,000, and the treaty with Panama guarantees an annuity, beginning 1913, of \$250,000 to the Republic of Panama. The sum of these four items is \$15,500,000. If to this there be added 1% per annum on \$375,000,000 to accumulate a fund to amortize the investment, the total annual expenses will be \$19,250,000. Of course, this revenue must come from the shipping using this canal.

The shipping using the Panama canal during the early years of its operation will probably have an aggregate net tonnage of about 10,500,000 tons. At the beginning of the operation of the canal, coastwise American shipping will probably amount to 1,000,000 net tons of this traffic. By the end of the first decade, *i. e.*, 1925, it is probable that the total net tonnage of shipping passing through the canal will amount to about 17,000,000 tons, of which at least 2,000,000 net tons will be contributed by our coastwise shipping.

The tolls upon merchant vessels have been fixed by the President at \$1.20 per net ton. It is thus possible that the revenues derived from the canal during the early years of its operation might average about \$12,600,000 per annum, if all vessels, American and foreign, were to pay tolls. If the coastwise shipping is exempted from tolls, the initial receipts from the canal will amount to less than \$11,500,000 during the early years of operation. By 1925, the total traffic of 17,000,000 net tons might, if the rate of tolls were maintained at \$1.20 per ton, yield a possible revenue of \$20,400,000 if all ships, American and foreign, were required to pay the canal levies. In all probability, however, the rate of tolls will have been reduced to \$1.00 per net ton by 1925, thus reducing the possible aggregate revenue to \$17,000,000. The coastwise shipping of the United States in 1925 will doubtless contribute at least 2,000,000 of the probable 17,000,000 net tons of aggregate traffic. Thus,

if the coastwise shipping does not pay tolls in 1925, and the rate of tolls is \$1.00 per net ton, the probable revenue of the Panama canal will then be \$15,000,000 a year, or somewhat less than the estimated annual outlays for operation, zone sanitation, government, the Panama annuity, and the interest on the amount invested in the canal.

The United States Government should adhere to business principles in the management of the Panama canal. While tolls levied at Panama should be low enough to permit commerce to derive substantial benefits from the canal, and while the charges for the use of the waterway should be well within what the traffic will bear, business prudence and political wisdom demand that the canal shall be commercially self-supporting, providing revenues large enough to enable the canal to carry itself, can be secured without unwisely restricting traffic. The tolls of \$1.20 per net ton, as established by the President, will not unduly restrict the use of the canal, even by shipping least benefited by the waterway. Coastwise carriers between the two seaboard of the United States will derive the maximum benefit from the canal, and a rate at least three times the one established might be paid by coastwise carriers without seriously restricting their use of the waterway.

The canal will cost the United States Government \$375,000,000, much of which has been, or will be, secured by borrowing funds. The interest and principal of this debt must be paid either from funds secured by general taxes or from the revenues derived from canal tolls. Public expenditures are increasing rapidly. Funds are required in increasing amount for the promotion of the public health, for irrigation and reclamation, and for maintaining the military power and naval prestige of the United States. Large expenditures upon rivers and harbors are urgently needed. Taxes must inevitably increase. The demands upon the United States are certain to be much greater in the future than they have been in the past, and it does not seem wise for the federal government to construct and maintain, at the expense of the general budget, such a costly public work as the Panama canal. Those who derive immediate benefit from the use of the Panama canal may properly return to the government a portion of the profits secured from using the canal, provided this policy can be followed out without burdening commerce. It should be the policy of the United States to apply business principles to the management of the Panama canal and to prevent its being a continuing burden upon the general Treasury and upon the taxpayers of the United States.

THE CHICAGO PLAN

CHARLES H. WACKER

Presented at the Annual Meeting January 8, 1913.

City planning—the work of building for the future as well as the present—is now recognized the world over as a great practical necessity. The city workshop is the greatest of all workshops because it involves the welfare of every man, woman, and child, of every class in the city. A school devoted entirely to the study of city planning has been opened in Berlin. Every phase of the growth and building of the city is viewed there in a scientific manner. Nothing is left to chance. The German city begins at the bottom and builds up.

New problems, and very serious ones, are confronting all nations that have large cities within their limits. At the conclusion of the Civil War 5% of the population of the United States lived in cities, as against 42% now living in cities. Of the entire population of our country today, 12% live in three cities alone—greater New York, Chicago, and Philadelphia. City problems have grown with city populations. Once gas, electric light, pure water, sewerage, and schools were the city problems. The problem of our great cities today, and for the next generation, is and will be to provide light, air, ample means for healthful recreation, relief from congestion, facilitation of traffic, housing of the poor, scientific organization of charities, better public improvements and more attractive surroundings for the multitudes swarming to the cities.

Within recent years civilized nations have become alarmed when, on seeking recruits for the army from their great cities, they have learned how few could pass muster because of their deteriorated physical condition. This alone is sufficient evidence of the need for more ample means of healthful recreation, more and wider streets, greater park and playground areas, and better surroundings generally. We all favor every phase of conservation, and we should favor it, because this country is, and has been, the most wasteful of all countries. I submit to you, then, that every human life is a national asset. Why not conserve that? Have we seriously undertaken the conservation of human life?

Because of this condition, the greatest issue confronting American municipalities today is right citizenship in relation to city planning. Right city planning is basic. A proper city plan, officially adopted and realized, for guiding the growth of a city in an orderly and systematic way, practically affords a solution of the chief problems confronting our constantly expanding municipalities.

European cities have a distinct advantage over American cities in city planning. Experience has taught them that disorder means disaster. In Germany, France, and England, where vast city planning projects are being carried out, the advantage lies in the fact

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that the plan originates with the municipality; its realization is usually aided financially by the government; and its direction is to some extent under government supervision.

In America, generally speaking, these favorable conditions are lacking. Here city planning originates, at least usually, as in the case of the Plan of Chicago, with a small group of public-spirited citizens. Then follows a long and arduous campaign of education with the people to arouse general interest in the city's welfare. When that is accomplished, usually an expression in the form of a popular demand follows, for it must be remembered that nothing is accomplished by imperial decree in this country. The ballot must go before the builder. Plans are then submitted to city authorities, and the long and tedious process of administrative machinery, necessitated by absurd legal and financial procedure and limitations, ensues, until finally something tangible is accomplished. Achievements are made only in proportion as the people have gained knowledge of city interests.

In the great forward urge for orderly development of American cities, therefore, it is not to be expected that Chicago, with her proud record of achievement, will stand still in the presence of her opportunities. The movement for better civic conditions is on throughout the world. The stirrings of the new impulse will not die out without accomplishment of the possibilities that lie before Chicago. The history of cities, both ancient and modern, has taught Chicago that its way to continued greatness and increased prosperity, lies in making the city convenient and healthful for the ever increasing numbers of its citizens.

Chicago's problem has become that of making the best use of its central location and its resources, which have already served to draw together more than two million people, and are clearly destined, inasmuch as fifty million Americans now live within twenty hours of Chicago, to make the city America's greatest center of trade and residence. Chicago's greatest duty is to plan now for that development which promotes present content and insures permanence to its future. Instead of going on in a haphazard, disjointed, unscientific and uneconomical manner, as we have been building in Chicago, we should now begin to follow the Plan of Chicago, which is scientific and carefully worked out to direct the future growth of our city in an orderly way.

The ten objects of the Plan of Chicago are as follows:

First: To direct the future growth of our city in an orderly, systematic, and symmetrical way, so that Chicago may attain a metropolitan character, and may retain her position among the great cities of the world.

Second: To educate the people upon the importance of city planning and demonstrate to them that city planning is basic for and co-related with better conditions, both hygienic and æsthetic.

Third: To adopt a scientifically and carefully elaborated plan, which is not to be changed in its essentials. It is obvious that hygienic measures must keep pace with the increasing erudition resulting from scientific research, and that prospective growth must take cognizance of such expedient hygienic and philanthropic advantages and necessities as changing conditions may demand in the future.

Fourth: To provide a plan for the whole people, and particularly for those who cannot afford to go elsewhere in search of recreation.

Fifth: To reclaim for the people the beautiful shores of Lake Michigan, and to provide more convenient and direct transportation thereto, and in this way make our city more healthful, pleasant, and attractive.

Sixth: To rearrange the streets and highways where that is demanded by intolerable conditions of congestion or inconvenience.

Seventh: To provide, along proper lines, for the growth of the city, park areas, small parks, playgrounds, bathing beaches, recreation piers, and boulevards.

Eighth: To capitalize our luxuries, our conveniences and our attractiveness.

Ninth: To convince the people that delay will make the execution of many of the important and now feasible features impossible, the practical impractical, the possible unattainable, and the economical extravagant.

Tenth: To convince the people that aside from its æsthetic and hygienic value, the development of our city, symmetrically and along well-planned lines, will prove an actual commercial asset of incalculable value to every citizen, be he rich or poor, and that we cannot longer afford to grow in the present haphazard, disorderly, and wasteful manner.

The Chicago Plan Commission, under whose direction the work of the Plan of Chicago is being carried out (the Plan created by the late Daniel Hudson Burnham, America's most famous city planner, under the direction of the Commercial Club of Chicago, and presented by that club to the city for official development), has directed its entire attention, since its organization two years ago, to three of the major phases of the Plan of Chicago—the Twelfth Street improvement, the Michigan Avenue north and south boulevard connecting link, and the great south shore lake front development—in connection with a city-wide educational campaign, embracing the distributing gratis of 165,000 copies of "Chicago's Greatest Issue—an Official Plan," and the installation in our schools of "The Manual of the Plan of Chicago," of which over 30,000 copies were used last year. In addition, hundreds of illustrated lectures have been delivered in all parts of the city and before all sorts of audiences. Over fifty American cities and more than twenty of the larger cities of Europe have requested copies of our two books, and many of

the progressive cities of our own country have asked us to deliver our plan lecture before their citizens.

The first major step in carrying out the Plan of Chicago under the direction of the Chicago Plan Commission, is the widening of Twelfth Street, from its present width of 66 ft. to 108 ft., by taking all of the property, or 42 ft., from the south side of the street, from Ashland Avenue to Canal Street, and widening to 118 ft., by taking 52 ft. from the south side of the street from Canal Street to Michigan Avenue. The street will be carried on down to the lake shore widened to 118 ft. from Michigan Avenue on, through an agreement reached between the Illinois Central Railroad Company and the South Park Commissioners last year.

The importance of the improvement of Twelfth Street is best understood when it is realized that that street is the only through thoroughfare without a jog or interruption between Harrison and Twenty-second streets. It is already an intensely busy thoroughfare and greatly congested. The center of population of the city today is at the corner of Twentieth and Fisk streets. Traffic and the growth of the city are gradually moving in a southwesterly direction, and adequate provision must be made for a suitable outlet from that district to the present business center of the city. Under the improvement proposed, Twelfth Street is destined to become one of the most important arteries in the city, and in all probability the most important railroad thoroughfare in the world, for it is planned to have grouped on the south side of the new Twelfth Street many important railroad lines which now terminate in the immediate downtown section of the city. Plans for the new Twelfth Street bridge are now under way. This bridge is to be of the bascule type, and when finished will be the widest and one of the finest bridges in the city. The cost will be \$480,000, half of which has been provided for by the Sanitary District and the other half by the city.

The importance of the Twelfth Street improvement in connection with the Plan of Chicago is because it forms the southern boundary of what is known as the "quadrangle," or the foundation of the street circulatory system of the entire plan. The four streets composing the "quadrangle," it is believed, are destined to bear the heaviest traffic of any four streets in the city of Chicago. These streets are, Twelfth Street on the south; Halsted Street on the west—which is to be widened and improved; Chicago Avenue on the north—already sufficiently wide; and Michigan Avenue on the east.

The second important part of the Plan of Chicago to be completed, and which is now well under way, is the widening and projection of Michigan Avenue north across the river. The present Michigan Avenue between Twelfth and Randolph streets is one of the finest business thoroughfares in the world. The transformation of that part of the street has almost entirely taken place within the

past ten years. Nearly all of the splendid commercial and social edifices and hotels lining the western boundary have been erected in the past ten years. It is a libel upon the common sense and intelligence of the community that this should be so, and that the great work of improvement should terminate at Randolph Street in an entrance to a narrow gap, frightfully congested, dangerous to life and limb, and a menace to traffic and industry from that point on to Lincoln Parkway.

On July 6, 1911, the Executive Committee of the Chicago Plan Commission unanimously adopted Plan No. 3 for the completion of the "boulevard link." This provides for a two-level street from building line to building line, to extend from Lake Street to Ohio Street. All shops, stores, and buildings of whatsoever nature will have their entrances and shop windows on the upper, or boulevard, level. The lower level will be used for receiving and shipping purposes. There are, in round figures, 60,000 vehicles of all descriptions traversing and crossing Michigan Avenue in that section every twelve hours of every working day in the year. It is obvious that by the two level system,—putting the automobiles and light traffic above and the heavy teaming below,—traffic-delays will be obviated, and Michigan Avenue will not only be reclaimed for high class property, but will become noted as one of the most unique and remarkable thoroughfares in the world.

Michigan Avenue is to be widened from 66 to 130 ft., 64 ft. to be taken from the east side of Michigan Avenue from Randolph Street, north to the river, terminating in a plaza approximately 250 ft. wide. North of the river the plan provides for the widening of Pine Street to 141 ft. by taking the necessary land from the west side of the street, from Chicago Avenue to the river, terminating in a plaza approximately 250 ft. wide on the north side of the river.

The grade of the street from Lake Street to South Water Street is to be 2%, from Ohio to Indiana 3%, and the distance between these two points to be practically level, with a double-deck bascule bridge over the river. Approaches to the lower deck for teaming to be 2.5% south of river, and 3% north of river, instead of approximately 5% as at present. Stairways are to be placed for access to the upper street at the river abutments north and south, and at Indiana, Illinois, and South Water streets. No one can estimate the value to the entire city of widening and projecting Michigan Avenue as proposed by the Chicago Plan Commission. Delayed five years, the cost will increase 50%. In ten years it will be doubled. The time is at hand to do it economically and with all conditions ripe.

Following closely the Michigan Avenue improvement is the vast plan for the reclamation and beautification of the south shore of the lake from Grant to Jackson parks. Under this plan it will be possible to locate the great Field Museum of Natural History near the present site of the Illinois Central depot. The attendance

at the Art Institute in 1911 was 873,918. At the Field Museum it was 220,000. The Art Institute attendance was four times that of the Field Museum, largely due to the downtown location of the Institute.

No public improvement that ever could be accomplished by the city of Chicago would be more wise, economically beneficial, and generally appreciated by the people than the creation of a large additional park space along the water front of the city by the construction of breakwaters for the retention and utilization of Chicago's vast amount of waste material available for such purpose. New York is already utilizing her waste material in building new land at her water's edge. Is there any reason why Chicago cannot do the same?

I have repeatedly made the statement in public, when advancing the Plan of Chicago, that it is little less than a crime that Chicago expended \$60,000,000 in building the Drainage Canal for the purpose of clarifying the city's water supply and then to permit the waters of the lake to again become polluted by the dumping therein of the offal of the city. This important hygienic feature is only one phase of the question. It presents an economic side of the utmost importance. Great expense is involved in carrying by lighterage much of Chicago's waste material and dumping it far out into the lake. This also permits the shameful waste of a vast amount of valuable material that could be utilized at practically no cost to the city in developing the lake front for park playgrounds for the enjoyment of all the people; where family picnics, baseball, tennis, and all manner of outdoor sports may be freely indulged in. The establishment of this health and pleasure giving possibility would cause a tide of gratitude to flow towards the creators thereof that nothing in all time could stem or stop. The result would be that instead of endangering the public health of our citizens, means would be provided to conserve that most valuable asset. The city would also gain realty worth many millions.

It is not contemplated that this work shall be accomplished in a day or a year, but to gradually create this park as rapidly as can be. Figures prove that from 75 to 100 acres each year could be made by utilizing the waste material of Chicago, and practically at no cost. The annual product of waste material of Chicago is 4,600,000 cu. yd., of which 2,000,000 cu. yd. go into the lake. This is from excavation material alone. It costs 80c per load of 2 cu. yd. by private contract to remove 1,000,000 loads each year out into the lake, and an additional 70c or 80c per load to haul the 1,000,000 loads of excavation material by wagon from where it originates to the disposal stations. When the wagons are once loaded, it would be just as easy for the contractor to carry it to the lake front and to deposit it, as to carry it to the disposal stations, hence there would be a saving of the additional 80c per load required to take it out into the lake. Add to this 20c per load for loading and reloading

at the disposal stations, and \$1.00 per load for 1,000,000 loads per year, from private contractors, is what the city could realize from that source alone. A fine annual sum to build breakwaters with, while the land—from 75 to 100 acres per year—is creating itself for nothing; priceless land. Did any city ever have such an opportunity?

In 1909 the city hauled 1,200,000 cu. yd. of ashes and refuse to the dumps of the city. These are being rapidly filled. It is only a question of time when new dumping places, far removed from the city, will have to be located, and reached only by rail at great expense.

When the lake front improvement along the south shore is completed, the people of Chicago will get the most imposing waterfront of any city in the world, offering our people unlimited opportunities for recreation, unlimited relief for the multitudes in the heat of summer on this great public playground at our city's front door, and unlimited enjoyment of winter sports upon the frozen lagoons—an all-the-year, every-day-in-the-week joy to all Chicago and all her guests, upon this 1,500 new acres of park to be added to Chicago's present area.

It is the bounden duty of every loyal Chicagoan to put his influence back of the work of the Chicago Plan Commission. Favorable action by all of the people must be had before any phase of the plan can be realized. The sooner we begin actual construction work on the Twelfth Street improvement, the Michigan Avenue connecting link improvement, and the great outer parkway lake front improvement, the sooner the incalculable benefits which will inevitably accrue to all our citizens will be realized.

SOME ECONOMICAL APPLICATIONS OF THE STORAGE BATTERY

J. LESTER WOODBRIDGE.*

Presented at a Joint Meeting of the Electrical Section W. S. E. and the Chicago Section A. I. E. E., November 25, 1912.

It is impossible, in a paper of this kind, to cover all of the multitudinous applications of the storage battery which have developed since its first introduction into commercial service. This paper will, therefore, be confined to a brief reference to those peculiar characteristics of the storage battery which distinguish it from other types of electrical apparatus, and a few illustrations of some of the more important applications in which these characteristics make for economy.

The storage battery differs from all other devices for the transformation of energy in two respects:

First, the time when it receives energy is always different from the time when such energy is delivered, whereas in other transforming devices the receipt and delivery of energy is always simultaneous.

Second, the rate at which energy is received bears no necessary relation to the rate at which it is delivered. In other apparatus these rates, neglecting losses, must be identical. Some exceptions to the above statements may, of course, be noted, such as the storage capacity of a steam boiler, but these exceptions are practically insignificant. Other special features of the storage battery, such as the possibility of effecting voltage and current transformation by altering the grouping of the cells, as well as the feature of portability, are sometimes utilized. But the economies which may be effected by the operation of a storage battery in connection with a large power generating and distributing system are, in general, due to the two peculiar characteristics first noted, and the resulting ability to create the most economical conditions of generation and distribution, independent of the time and rate of the actual demand.

There is still another characteristic of the storage battery which is utilized to a large extent, and has a very decided bearing upon the economy of operation, and that is its readiness to deliver energy instantly without requiring any considerable interval of time for preparation. This feature in itself permits more economical operation of a generating plant which is provided with storage battery reserve, even when the battery is not actually charged and discharged in regular daily service. The mere presence of a reservoir of power ready to be drawn upon in case of need will, in many cases, permit the rest of the power-station equipment to be operated under more

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efficient conditions of loading than would otherwise be the case. Without such a reserve, the question of continuity of service will often predominate and prevent the most economical operation.

In the operation of any specific combination of generating apparatus and distribution system with storage battery auxiliaries, the load should be so apportioned that each class of apparatus handles the part which it can handle with maximum economy. Demands which are small as compared to the capacity of the generating machinery, and those which, although comparatively heavy, are of short duration, are uneconomical to supply from such machinery, whereas they are handled by a storage battery at maximum economy. Economy is used here in its broadest sense, signifying the ultimate financial results and taking into account both fixed and operating costs.

In designing a storage battery installation and determining the proper method of operation, care should be taken, therefore, to determine what part of the work the battery should do, and what part it should not do. In many cases the dividing line has not been properly drawn, and batteries have often been called upon to do work which could be handled with greater economy by the generating apparatus, whereas in other cases the generating apparatus has carried parts of the load which could be more economically handled by the battery. At one time there appeared to be a tendency on the part of engineers, in specifying a regulating storage equipment, to call for very close load regulation, sometimes as close as 5% on either side of the average. In most cases this refinement of regulation was wholly unnecessary, and, without reducing the size of the generating apparatus, involved an unnecessarily large investment for the storage battery, and a lower efficiency of plant operation than would have resulted if a substantial part of the load fluctuations had been carried by the generating machinery, leaving the battery to handle only those extreme peaks which would otherwise have called for increased generator capacity and a reduction in the average loading of the units in operation.

An examination of the load curve of many generating plants will show that this curve consists of a series of more or less sustained peaks occurring sometimes at regular intervals, and sometimes at irregular intervals, upon which are superimposed severe momentary fluctuations. Automatic battery regulating apparatus designed to hold the generator load substantially constant will compel the battery to carry not only the momentary fluctuations but also the sustained peaks. In almost all cases these sustained peaks, or the greater part of them, could be handled by the generating apparatus without overtaxing their capacity, or impairing their efficiency. In many cases, also, a portion of the momentary peaks could be economically handled by the generators. In such cases the storage battery should not be called upon to do the work which should properly fall upon other parts of the installation.

In order to provide for a proper division of load between the storage battery and the generators, and to accomplish this division automatically, several different types of auxiliary regulating apparatus have been developed which will be briefly described below.

The first of these pieces of apparatus is the carbon regulator, which is so well known and has been so often described that it will be given only the briefest possible mention here. It consists of two sets of piles of carbon discs arranged on opposite sides of the fulcrum of a lever in such a way that pressure applied to the lever will compress one set of piles and relieve the pressure on the other, or vice versa, thus varying the contact resistance between the discs. The pressure produced by the lever is controlled by an adjustable spring at one end, and a solenoid at the other, the latter carrying the output of the generating units, or a current proportional thereto. The carbon piles are connected in series across a section of the battery, and the field of the booster or exciter which controls the operation of the battery is connected into a circuit between the

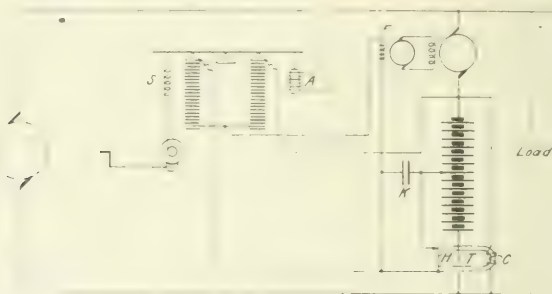


Fig. 1.

middle point of the series of carbon piles and the middle point of the battery section above referred to. The diagram of these connections is shown in Fig. 1. The tension of the spring *S* may be adjusted to balance any desired average load in the solenoid *F*, under which conditions there would be no flow of current through the field coil *F*, and the battery would neither charge nor discharge. Any slight change of load on the generators above or below the value for which this adjustment has been made will vary the pressure on the carbon piles and cause a flow of current in the regulating field coil to cause the battery to charge or discharge, and thus relieve the generating units of all of the fluctuation of load, except the small amount required to actuate the regulator. This regulator will, therefore, throw upon the battery practically all fluctuations of load, whether large or small, rapid or sustained.

In order to permit the regulator to discriminate between quick fluctuations and those which are more sustained, the automatic average adjuster has been developed. This is an adjunct to the carbon

regulator, and its connections are shown in Fig. 2. It consists of a small motor *M* geared to the drum *D* which adjusts the tension of the carbon regulator spring. The armature of this motor is connected across the direct current bus bars in series with a comparatively high resistance which permits a substantially constant current to pass through the armature, regardless of the counter e. m. f. developed in the latter.

The field of the motor is connected at one end to the middle point of the battery, and at the other end by means of the contact-making voltmeter *V* to either the positive or the negative terminal of the battery, according to whether the battery voltage which is applied to the actuating solenoid of this voltmeter is above or below the floating point. The apparatus is so adjusted that whenever the battery voltage drops, as a result of discharge, the motor field is connected to start the motor in the direction to increase the tension of the carbon regulator spring, thus requiring a greater current in the solenoid to balance it. As a result, the generator load is in-

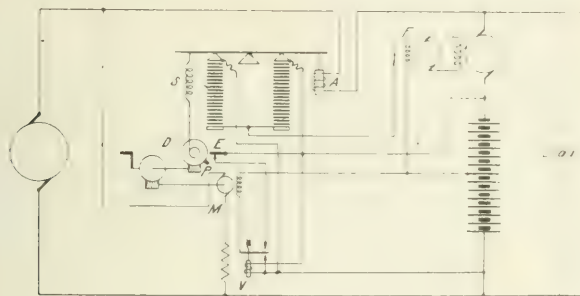


Fig. 2.

creased, and the battery is relieved of the discharge to which it was subjected. On the other hand, if the battery is charging, and its voltage rises, the motor is operated in the opposite direction, reducing the generator load and relieving the battery of the charging current. The changes produced by this average adjuster are, however, comparatively slow, and, in fact, the speed at which they occur may be adjusted to meet the local conditions obtaining in each individual case. As a result of this method of operation, the battery handles all of the quick fluctuations of load, while the sustained peaks, which in reality constitute slow changes in the average load, are transferred to the generators. The drum *D*, which varies the tension of the carbon regulator spring, is provided with a projecting arm *P* arranged to open a switch *E* in the motor field circuit when the spring has been wound up to a point corresponding to the maximum capacity of the generators. When this point is reached, the average adjuster motor stops, and no additional load

can be thrown on the generators. The battery must then take all of the fluctuations of load above this point, whether rapid or sustained. This limit switch is located in that control circuit which produces an increase of generator load. The circuit corresponding to a decrease of generator load is not, however, interrupted, so that as soon as the demand on the plant falls off sufficiently to cause the battery to charge, the motor will operate in the opposite direction, unwinding the spring and relieving the load on the generators, at the same time closing the limit switch *E* and restoring the normal conditions of operation.

This average adjuster, by relieving the batteries of a large amount of unnecessary work, which could be more economically handled by the generating units, and also by eliminating the heavy periodic gassing charges to which the battery would otherwise be subjected whenever the demand should drop considerably below the average for a long period of time, has very materially improved the efficiency of operation and reduced the cost of battery maintenance without in any way impairing the effectiveness of the battery in handling those fluctuations of load which it can handle more economically than the generators.

Under some conditions it is desirable to permit the generating units to handle all of the fluctuations of load up to a certain point and cause the battery to take all fluctuations beyond this point. This is accomplished by means of an adjustable stop shown at *Q* in Fig. 3. This stop opposes the tension of the carbon regulator spring and may be adjusted to produce such pressure on the carbon piles as to hold the battery at the floating point, neither charging nor discharging, or to produce a small net charge at constant rate. The spring is then adjusted to balance the maximum load at which it is desired to limit the generator output. For all loads below this point, the lever arm of the carbon regulator will be resting on the stop, and the regulator will be inactive. Whenever the generator load slightly exceeds the spring adjustment, the lever will be raised off of the stop by the pull of the solenoid, and the carbon regulator will operate in the normal manner to cause the battery to discharge and prevent any fluctuations of load above this point from falling on the generators.

In some situations it is found desirable to limit the battery discharge at a certain point in order, for example, to protect the battery booster, without opening the battery circuit breaker. To accomplish this the current stop, shown in Fig. 4, has been developed. This consists of an electro-magnet *T* energized by the current in the battery circuit which actuates a vibrating contact arm *H*. The contact, when closed, completes the exciter field circuit, permitting the normal operation of the regulating apparatus. Whenever the current in the battery circuit exceeds the value for which the current stop has been adjusted, this contact is opened, thus momentarily interrupting the current in the exciter field. If

this circuit remained open, the battery current would drop to zero, but as soon as it has dropped below the point for which the current stop has been adjusted, the field circuit is again closed and normal conditions restored. The result is a rapid vibration of the contact point, which holds the current in the exciter field at an average value just sufficient to maintain the battery discharge at the desired

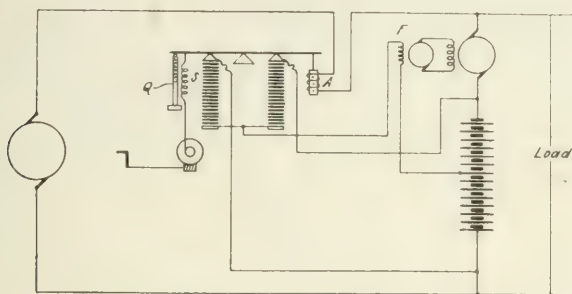


Fig. 3.

maximum value without permitting it to exceed this limit. An electrolytic condenser *K* is connected across the break in the exciter field circuit to suppress the spark. A polarizing coil *C* may be added to the electro-magnet to provide different limiting values for charge and discharge. Figure 5 is a curve of battery charge and discharge, showing the effect of the operation of this current

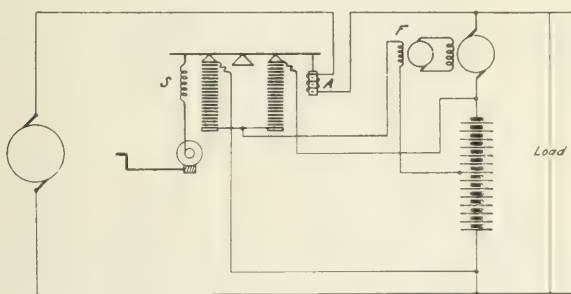


Fig. 4.

stop. It will be seen that the discharge is limited to 600 amperes and the charge to 300 amperes.

As illustrations of the general principles outlined above, a few examples of the application of storage batteries to the generation and distribution of power in a few concrete cases will now be given.

Figure 6 is the total load curve of an electric railway system

in a city of some 400,000 inhabitants. This load was handled by three power houses developing direct current at 575 volts.

Figure 7 shows the varying cost of power production on this system as affected by the load factor. The load factor of the curve shown in Fig. 6 is 42½%. If all the load above 42,000 amperes had

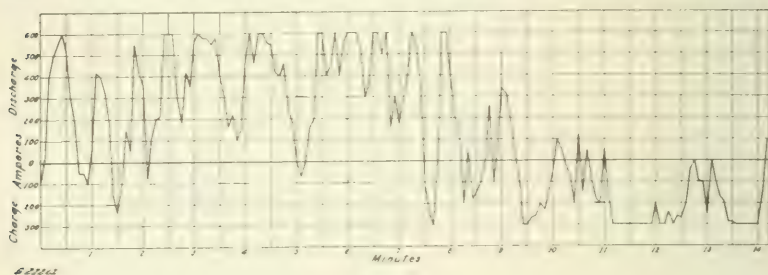


Fig. 5.

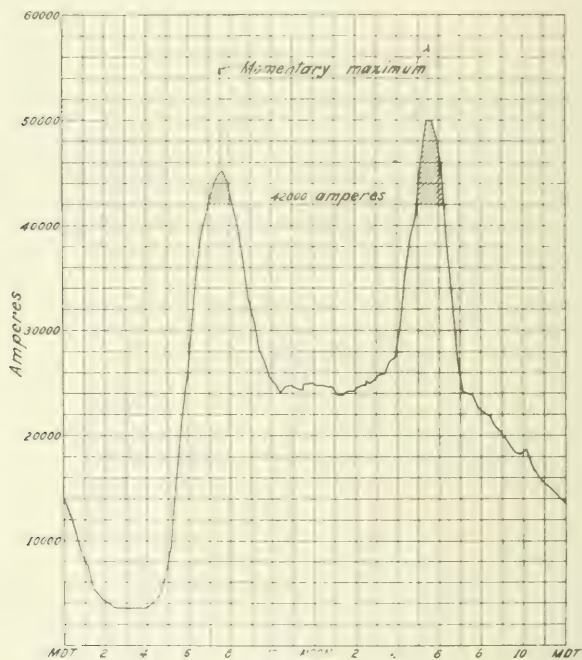


Fig. 6.

been taken by a storage battery, the load factor would have been increased to 50%. At 42½% load factor, the cost of producing power, as shown in Fig. 7, is 8.9 mills per kw. hour, while at 50% load factor, this cost is reduced to 8 mills. The total output shown

on the load curve is approximately 294,000 kw. hours. This at 8.9 mills amounts to \$2,616.00. The energy represented by the peaks above 42,000 amperes is approximately 5,480 kw. hours, leaving 288,520 kw. hours below the 42,000 ampere line. The cost of producing this last amount of energy at 8 mills per kw. hour (corresponding to 50% load factor) is \$2,308.00. The difference between these two amounts, namely, \$308.00, represents the cost of producing the peaks above 42,000 amperes; that is, the cost of 5,480 kw. hours. This cost is, therefore, 56 mills per kw. hour. It will be noted that this latter figure is just seven times the cost per unit of output for the energy below the 42,000 ampere line.

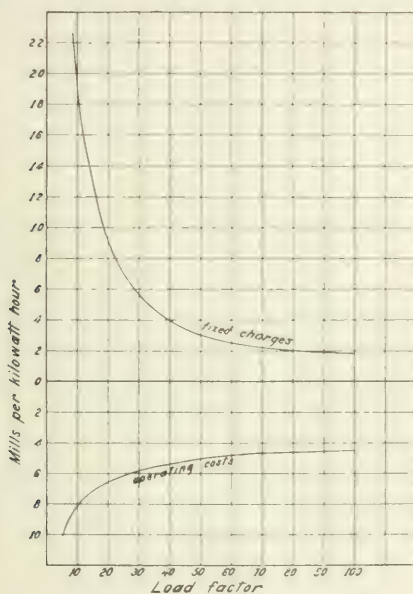


Fig. 7.

The cost of producing the peak energy, if this energy were developed between the peaks and stored in a storage battery, allowing 80% battery efficiency, would amount to about \$55.00 at 8 mills per kw. hour. The difference between \$308.00 and \$55.00, or \$253.00, is the daily saving that would be effected by the application of a storage battery to the above situation. This saving on the basis of 300 days per annum would amount to a yearly saving of \$75,000. The cost of such a battery installation, including battery house, should not exceed \$350,000. Allowing 8% for maintenance, depreciation, insurance, and taxes, leaves a saving of \$47,000 per annum, or over 13%, as interest on the investment.

The curve shown in Fig. 7 is based on actual data obtained from the operation of the plants to which it applies, the fixed charges being figured on a rather low valuation of the property determined by a municipal commission.

A diagram similar to Fig. 7 was presented by Mr. H. G. Stott, in the discussion of his paper presented at the meeting of the American Institute of Electrical Engineers in New York on March 8, 1910, and will be found on page 248 of the Proceedings for 1910. This diagram, however, applies to a steam turbine plant of large capacity developing alternating current, and does not take into account the cost of transmission lines and transforming sub-stations for a direct current distribution system. The effect of including these items is to materially increase the fixed charges.

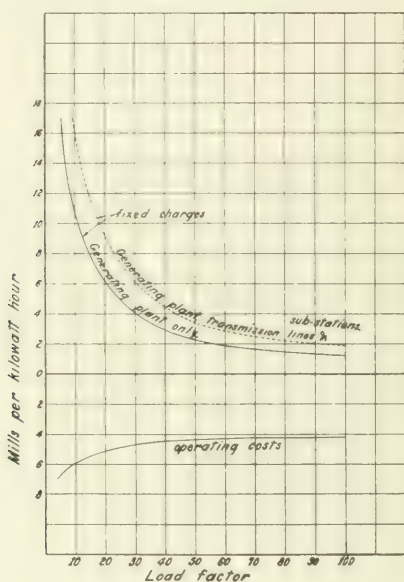


Fig. 8.

Figure 8 is a diagram in which are shown in full lines the curves given by Mr. Stott, and a dotted line derived from the upper curve by increasing its ordinates by 50% to provide for the increased interest, taxes, depreciation, etc., on transmission lines, conduits and transformer sub-stations.

The lower line representing operating costs has not been altered, inasmuch as the labor at sub-stations would not be materially changed by the operation of a storage battery, and the improved efficiency of the sub-station operation would be practically offset by the battery losses.

From this diagram it will be seen that the total cost per kw. hour at 42½% load factor is 8.51 mills, while at 50% load factor it is 7.66 mills. The former figure, applied to the total area of the load curve in Fig. 6, gives a total cost of \$2,501.00. The latter figure, applied to the area below the 42,000 ampere line, gives a total cost of \$2,209.00. The difference is \$292.00, which represents the cost of the peaks above 42,000 amperes. These peaks represent 5,480 kw. hours, so that the cost of the peak load per kw. hour is 53.2 mills. This again is nearly seven times the average cost per kw. hour at 50% load factor.

From the saving of \$292.00, as above determined, must be deducted the cost of power for charging the battery, amounting to 5,480 kw. hours at 7.66 mills, or \$42.00. This leaves a net saving of \$250.00 a day, or \$75,000 per annum, which is substantially the same as obtained in the previous illustrations. The battery capacity would, however, be somewhat less since the peak load shown is at the power house, and includes transmission and transformation losses, whereas the battery output would be figured net at the direct current bus bars. This difference, however, might be partially offset by the necessity of distributing the battery capacity at a number of different sub-stations.

The system from which the load diagram of Fig. 6 was taken has had in operation for a number of years five large storage battery installations distributed at different points, and utilized not only for relieving the main power stations of the peak loads, but also for maintaining better voltage on the line.

Figure 9 is a map showing the relative location of steam generating stations and storage batteries, and in Fig. 10 is the same load curve as that shown in Fig. 6, with the actual battery charge and discharge indicated. It will be noted that the batteries were not operated to cut off the peak loads at the power house along some definite horizontal line, but the battery discharge was continued well down the slope of the peak. This is due to the dual function of these batteries in not only relieving the power house of the peak loads, but also maintaining line voltage at a distance from the power house. During the evening rush hours, the maximum loads in the vicinity of some of these line batteries, located on the outskirts of the city, will be sustained for some time after the peak of the total load on the system has passed, owing to the movement of the traffic congestion from the centre of the system to its circumference.

The history of the growth of this electric railway system affords an interesting example of the application of storage batteries to the solution of the various engineering problems that arise in connection with the development and extension of this class of public service. There were originally two distinct trolley systems in this city, each having its own direct current power station located at *A* and *B*, respectively. When the load on power house *A* had

increased, calling for greater capacity, a storage battery was located at *D* adjacent to the power house to take the morning and evening peaks. In the meanwhile the problem of distribution on the longer lines was becoming serious, and a system of boosted feeders was introduced to improve the line voltage at the point *E*. Some of the older machines in the power house were converted into series boosters for this purpose. It was not long before the load increased



Fig. 9.

beyond the capacity of this boosting system, and a line battery was installed at *E* to operate in conjunction with the boosters which were then operated as shunt machines. When this battery was first installed, it was necessary to operate these boosters only on special days, such as holidays and Sundays, but a still further increase in the load made it necessary to operate them more and more frequently, until finally they were in operation every day. In the

meanwhile the two systems were consolidated, resulting in a better distribution of load, each power house feeding that part of the system nearest to it. Continued growth had, however, produced very low voltage and unsatisfactory operating conditions at several points, and finally two additional line batteries were installed at *F* and *G*, respectively. These batteries were charged during the lighter hours of the day, and discharged during the rush hours to maintain line voltage; at the same time, they relieved the power stations of an appreciable proportion of the peak load. About this time a competing line was built having a power house at *C*, and a

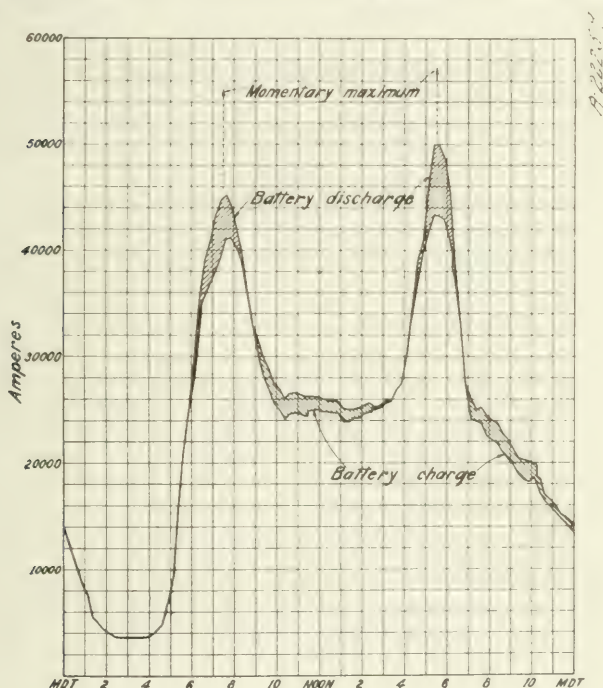


Fig. 10.

storage battery at *H*. This line was later included in the consolidation, and the load curve shown in Fig. 10 represents the combined load of all three systems.

Finally the increase of load reached a point where the distribution problem exceeded the limits of 600 volts transmission, even with the aid of boosters and storage batteries. Alternating current transmission with rotary converter sub-stations, which had been considered but rejected on many previous occasions on account of the large investment for the underground conduit system required, was now the only alternative. After giving careful consideration

to the question of building a new alternating current power house, a contract has been closed with the local illuminating company to supply current from its power house, *K*, to four sub-stations, located at *E*, *F*, *I* and *J*, on the out-skirts of the system. The two steam plants *A* and *B* will continue to operate for supplying the downtown load. A new battery is to be installed at sub-station *E* to replace the old installation, which now requires extensive renewal. The battery at *F* will be increased in number of cells to correspond to the increased voltage at that point. The battery at *H* will be moved to *I*, and an appropriate number of cells added, while the battery at *G* will be operated in conjunction with sub-station *J*, the booster and one pilot cell being located at *J*, and heavy copper cables now in service as feeders between the two points will be utilized to connect the battery with the sub-station, so that no attendance will be required at the battery. The machinery from power house *C* will be moved to power house *B*, the former power house being abandoned.

The terms of the power contract with the illuminating company provide for a demand charge based on the monthly one hour maximum demand, plus a charge for power on the kw. hour basis, and it is estimated that the reduction in the maximum demand effected by the batteries will produce a very material reduction in the power bill.

The history of the development of this system is a striking example of the flexibility of a storage battery in meeting changes of conditions which would ordinarily necessitate the entire abandonment of other types of apparatus as obsolete.

The case above cited is only one of the many instances illustrating the tendency toward the concentration of power generation under one management, and the purchase of power by transportation companies. The conditions in Chicago, which have been described on other occasions and are quite familiarly known, afford another illustration of this tendency. Here also the storage battery is employed on a large scale to reduce the power bills by cutting off the maximum peaks.

Another more recent illustration of this application of the storage battery may be found in a large city in the neighborhood of Niagara Falls. The railway and lighting companies in that city, while normally separate, are controlled by the same financial interests, and both of these companies purchase power from Niagara at rates which vary with the load factor. The effect which the operation of the battery will have on the bills for power, as well as the necessity for providing for the natural increase of load and the desire for better insurance against interruptions of service, have led the management of these companies to contract for four large batteries to be installed during the coming winter. These, in addition to a battery already in service at one of the railway sub-stations, will provide for a total of approximately 8,000 kw. of

storage battery capacity on the peak. Two of the four new batteries will be used on the direct current 3-wire circuit, while the other two will operate in connection with the railway load. The total load of this system for railway and lighting measured at the Niagara Falls power house is shown in Fig. 11, where the amount of the peak which can be taken off by the storage batteries, is indicated. It is estimated that the cost of power plant development, transmission lines, and sub-station machinery would be about double the cost of the batteries to handle the same amount of peak load.

As another illustration of the application of storage batteries in connection with power contracts of this kind, may be cited the battery installation which is in operation in connection with the

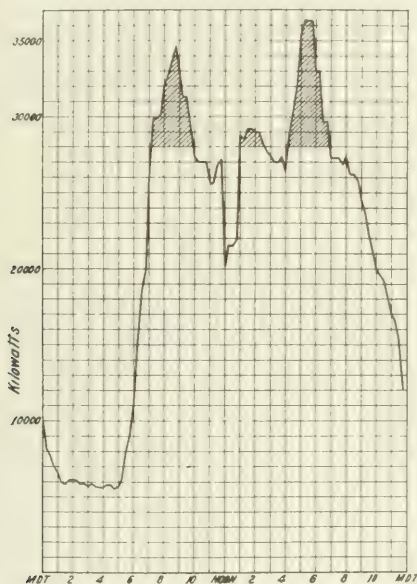


Fig. 11.

power supply for a large steam road tunnel electrification. In this case the contract demand is fixed by the maximum hourly average between 4 and 6 P. M. during the winter months, and the circuit breakers in the high tension feeders are set at 50% above this hourly maximum demand. If the hourly maximum should at any time increase above the previous record, or if it is found necessary to increase the circuit breaker setting, in order to avoid constant interruption of the power supply, the demand for which payment must be made on the yearly basis, under the terms of the contract, is increased proportionally. In this situation the battery regulating apparatus is provided with a stop such as is shown in Fig. 3, so that the battery is not called upon to discharge until the load on

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the rotary converters approaches the point which would call for an increase in the demand, and a subsequent increase in the power bills. At this point the battery begins to discharge, preventing any further increase in load on the power supply circuit. Figure 12 is a load curve showing the operation of the battery under these conditions.

Power contracts of this kind, in which the cost of power varies with the load factor, are becoming more and more numerous, and in most cases show a decided economy in the use of storage batter-

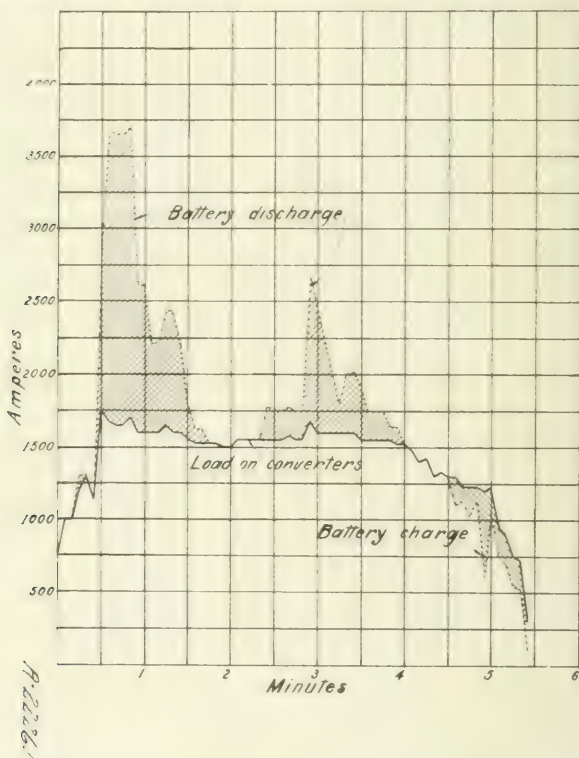


Fig. 12.

ies, provided their operation is properly controlled to meet the conditions imposed in the contract. The analysis of costs of power generation as affected by load factor given in the early part of this paper, clearly indicates the necessity of taking into account the load factor in such contracts, in order to protect the selling company. It seems evident, therefore, that wherever the load curve assumes a shape approximating those illustrated in this paper, the storage battery will prove an economical investment, whether the purchaser generates his own power or purchases it from another company.

THE EDISON STORAGE BATTERY

BY HAROLD H. SMITH.*

*Presented at a Joint Meeting of the Electrical Section W. S. E.
and the Chicago Section A. I. E. E., November 25, 1912.*

HISTORY.

The man who produced the Edison storage battery, if he had never produced anything, would probably have become famous for his unerring ability to predict the future needs of the public. This ability, coupled with his unswerving faith that nature holds in secret hiding all that is required for reasonable human needs, to be yielded up when the pressure of untiring perseverance is brought to bear, is responsible for the electric light, the commercial dynamo, the electric railway, and other luxuries too numerous to mention—luxuries which, true to his prediction, have become necessities.

Referring to his own account of the inception of the battery idea and its development, we find him saying that he started with the broad idea that displacing of horse-drawn vehicles in cities would be an enormous advance, and that for city use the ideal vehicle is the electric. He believed the battery then available was a serious drawback, and that nature would afford another more suitable reaction, so he started. "After a very large number of experiments," he goes on to say, "I at last found a reaction that, although very weak, was promising, and I pursued this for three years, finally producing the first type of nickel-iron-alkaline battery." This appeared in 1901. Defects were soon found, and improved types followed one another until in 1904 Type E was produced and put on the market. About 800 batteries were sold and soon proved their great superiority over any existing type of vehicle battery. Some of them are still in service, though it must be admitted they are very near the end of their usefulness. In about eight months certain unlooked-for faults were discovered and, in spite of the battery's good work, the order went forth to close the factory and withdraw the battery from the market. Persistent experimentation was again immediately entered upon, with many sleepless nights for all engaged in it, and in 1908 the present type was consummated, and placed before the public in the winter of 1908-09. At the present time the first battery sold is still making its regular daily rounds in delivery service in New York City. It has been working steadily since March, 1909. Some months earlier a battery was put in service in one of the Lansden Company's trucks in Newark, N. J. That battery is still in commission and a test made last May showed it to have an average capacity of 194 ampere-hours. It is rated at 150 ampere-hours.

*Chief of Research Department, Edison Storage Battery Co.

CONSTRUCTION.

The Edison battery is distinctive in its chemical and mechanical features, both of which contribute toward making it what it is electrically.

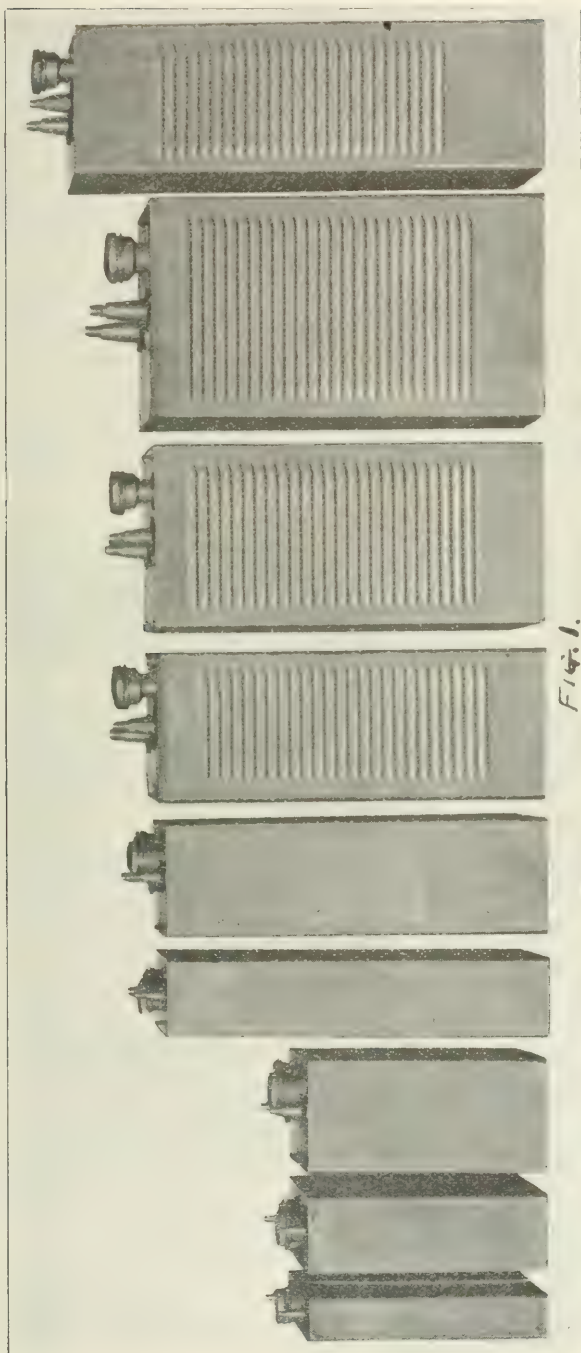
The active material of the positive plate is nickel hydrate, and that of the negative plate, iron oxide. The electrolyte is a 21% solution of caustic potash containing a small quantity of lithium hydrate.

The nickel active material is loaded into steel tubes in very thin layers, and between each two layers is a thinner layer of pure nickel, insuring good electrical contact between the remotest active material and the metallic container and grid. A very small percentage of mercury oxide, mixed before loading with the iron active material, performs a similar function in the negative plate. In this case the material is packed in flat sheet steel pockets instead of in tubes.

The tubes of the positive plate are manufactured from perforated steel ribbon which, by a very ingenious machine, is turned into the form of a closed spiral with double lapped seam. The resulting tubing is exceedingly strong. This tubing is cut into proper lengths and is placed in a machine which dumps in a small quantity of hydrate, and on top of this a layer of metallic flake, and then causes a weighted ramrod to fall by gravity, thus packing the material into a very compact mass. These operations are repeated about 300 times to each tube, and the loaded tube consists of this number of distinct layers of each material. The tubes are then pinched at both ends to form suitable terminals for clamping into the steel grid, and eight small, seamless, steel rings are slipped over each tube, giving it additional rigidity and strength, after which it is ready to be placed in the grid. The grid is a steel punching so formed that the tubes are placed beneath small ears and clamped firmly in position under very high hydraulic pressure.

The pockets of the negative plates are made from perforated steel ribbon also, in two halves, male and female. These halves are placed together and the boxes so formed are loaded in a tamping machine similar in principle to the one employed for tube loading. The loaded pockets are then subjected to additional pressure in a machine which also slightly crimps the edges so that they fit snugly into the interstices of the negative grid, likewise a punching of steel. The plate so formed is subjected to still another pressing operation in which the pockets are squeezed into intimate contact with the grid, their surfaces are corrugated to insure strength, and the material inside is compressed into hard solid cakes. The plates are now ready to be assembled.

The desired number of each kind is mounted on a steel rod to which the steel tapered pole is attached at right angles. The plates are spaced by means of washers of the proper width. Finally, on each end of the connecting rod is placed a lock washer and nut.



making a secure and durable mounting. The two groups of elements are intermeshed, small rubber pins are placed between the plates to keep them separated, and the unit is completed when grooved side insulators have been placed over the edges of the plates. It is now slipped into the containing jar or can, in the bottom of which has been placed an insulator upon which the plates rest, and sheets of hard rubber are put in at the ends, insulating the outside negative from the can. All is then ready for the top to be put on and welded in place. The can is of sheet steel corrugated for strength, bent into shape and welded by the oxy-acetylene flame along one side. The bottom is then welded in and, finally, when the elements are in place, the top is welded also, thus entirely sealing the cell, except for the combination valve and filler opening in the cover; and it cannot be reopened without ruining the can—very good evidence that it is not expected that it will ever have to be opened. The poles project through openings in the cover surrounded by a combination of hard and soft rubber washers and bushings, which effectually prevents the passage of gas or electrolyte.

When finished, the cells are coated with an insulating protective paint and assembled in trays similarly coated. The cell connectors are short copper rods, nickel plated and fitted with steel lugs having internal tapers corresponding to the taper of the cell poles. These are placed over the poles and forced into good contact by means of an ordinary nut.

All the steel parts of the cell, from the perforated ribbons, of which the tubes and pockets are made, to the can, are nickel-plated electrolytically, and then annealed at red heat in an atmosphere of hydrogen, thus rendering the plating free from the tendency to peel off.

I think you can now appreciate the great mechanical strength of this battery, and will recognize the value of this feature in all work where severe vibration or shock is likely to occur.

ELECTRICAL CHARACTERISTICS AND TESTS.

At the present time there are on the market two general types of cells known as Type A and Type B.

Type A is intended principally for use in electric vehicles. Its positive plates have 30 tubes each in two horizontal rows, and its negative, 24 pockets in three horizontal rows.

Type B is used principally for gasoline car ignition and lighting. In this type the positive plate is half the size of that in Type A, having only one row of 15 tubes of the same size. The negative has 16 pockets in two rows, the pockets being somewhat smaller than in Type A.

Each of these general types is subdivided according to the number of positive plates to the cell, and at present the complete list consists of eight types ranging in size from B2 to A12, the numeral

referring in each case to the number of positive plates. A special form of Type A cell has been developed for use in train lighting. It is similar to the regular cell in every way except that the can is higher, allowing more room for electrolyte. In every cell there is one more negative than positive, thus the A6 cell contains a total of 13 plates.

The following are the ratings of the various types as to rate of charge and discharge and capacity:

Types	B2	B4	B6	A4	A6	A8	A10	A12
Rated capacity, amp.-hrs.	40	80	120	150	225	300	375	450
Normal rate, amperes....	8	16	24	30	45	60	75	90

The voltage of any type cell, when discharging at normal rate, averages 1.2 volts. The normal rate is the same for charge and discharge, and the normal length of charge is seven hours. The rated output, it will be noted, is based on a discharge at normal rate for five hours. After the battery has been in use for some time, it will be found that the output has increased about 13% or 14%, and that by increasing the charge to ten or twelve hours, a discharge more than 25% above the rated capacity can be obtained. This length of charge is wasteful of energy and causes excessive gassing and dissipation of water from the electrolyte, so that one would hardly care to employ it except in cases of special requirement; it will not, however, harm the battery in any way.

The weight of a portable battery with reference to its energy output is a most important consideration. Taking into account the weights of trays, connectors, etc., this figure for Type A varies from 13.5 to 16.5 watt hours per pound, depending on the length of charge and, to a slight extent, on the size of cell.

Figure 2 shows characteristic curves of charge and discharge. The voltage during a charge of seven hours at constant normal rate rises rather rapidly during the first thirty or forty minutes, drops off a little, and then rises slowly until about the fifth hour, when it again takes a steeper upward trend, until finally, when the battery may be considered charged, the voltage will be between 1.80 and 1.85 volts per cell. The average voltage during charge is about 1.7 volts per cell.

At constant normal rate the voltage during discharge commences at about 1.45 volts, and, except for the rapid drop at the beginning and end, falls gradually to whatever voltage can be made use of. Usually this is in the neighborhood of 1.0 volt, but the battery will not be affected if the discharge be carried to any voltage down to zero.

The average internal resistance during discharge varies from 0.012 ohm per B2 to 0.001 ohm per A12, the others between, varying in inverse proportion to the number of positive tubes to the cell.

The Edison battery is peculiarly adapted to service in which

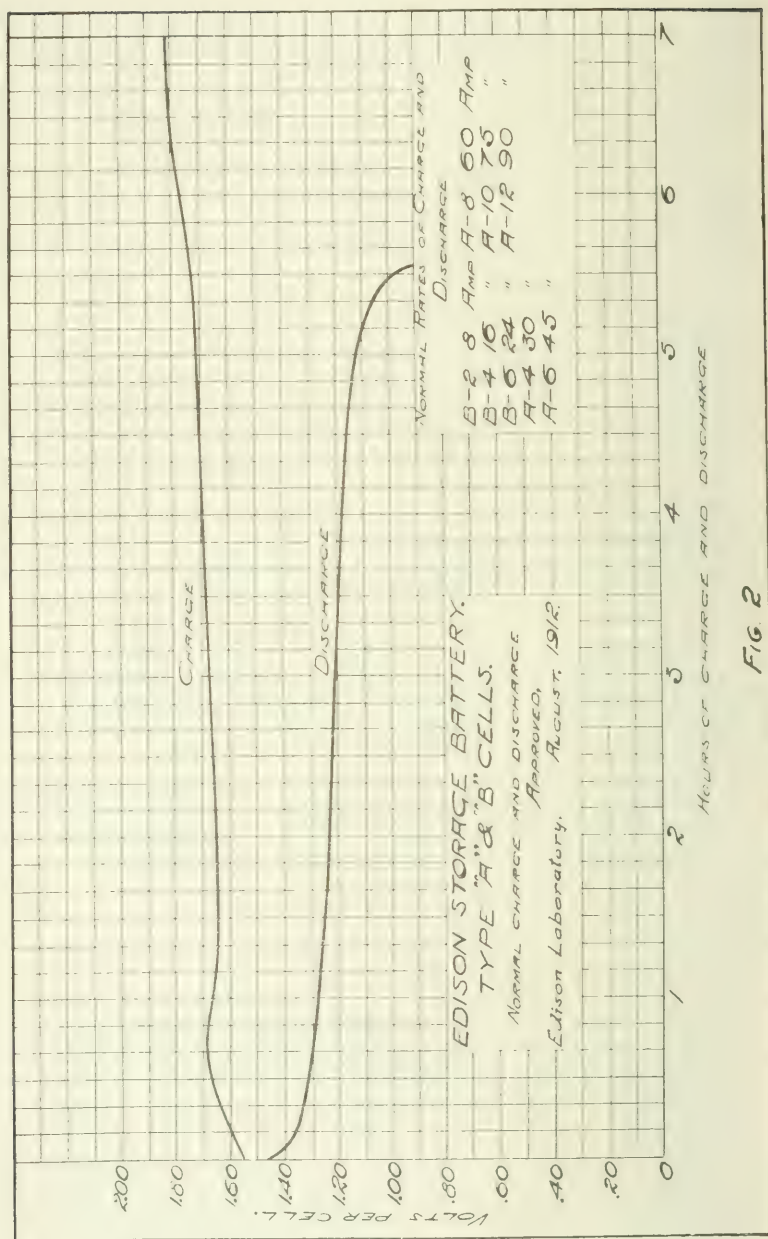


FIG 2

it is desirable to give, every now and then, a "boost" for a few odd moments and thus considerably augment the previous charge. It is possible, for example, for a storage battery street car to charge, during its five-minute lay-over at the end of the route, at five times normal rate and thereby augment the charge by an amount equivalent to a boost of twenty-five minutes at normal rate. Or a delivery truck may put in the equivalent of two hours' charge while the driver is at lunch. Current so put in is recovered at practically 100% ampere-hour efficiency. Such boosts will have no deleterious effect providing only that the temperature be kept within reasonable limits.

Questions as to the life of the Edison battery can be answered only in a very indefinite way, for no one knows what it is. All that can be said is that the oldest battery has been in service close to four years and is still good, that the guarantee that goes out with each vehicle battery is good for four years, and that we are only waiting for time to tell what the actual limit of useful life is. Laboratory endurance tests have been made as severe as possible, and yet the curve of Fig. 3 shows that the capacity is still above rating after 1,100 complete cycles of charge and discharge. This test has been conservatively regarded as being at least three times as severe as ordinary service conditions.

In the laboratory every effort has, of course, been made to discover what sort of treatment will cause injury to the battery. Chemical impurities introduced into the electrolyte will naturally be the cause of most severe injury, and we have found that the use of pure distilled water for replenishing what has been given off in the form of gas, is the only course safe to pursue for the best results. Yet it has been surprising to note that while many impurities have temporarily greatly affected the capacity, the battery will be restored to its previous condition, provided the adulteration has not proceeded too far, when the contaminated solution is rinsed out and replaced by fresh solution. I will speak especially of one notable case,—that of sea water, which one would naturally expect would mean summary death to a storage battery. I speak of this because I can quote from an actual case where an ignition set used in marine work was accidentally dropped into the sea, remained immersed for four days and was returned to the factory to determine if anything useful could be saved from it. The electrolyte was analyzed and found to contain a large percentage of salt water. The cells were simply rinsed, refilled with standard electrolyte and put on test. At first the voltage was a trifle low, but on the third run it was up to normal condition and has been all right ever since.

For mechanical abuse we have mounted trays of cells loose on a strong hand-truck and had it rammed into a stone wall 500 times, as hard as a good husky laborer could propel it. One of the cells was then mounted in a machine that lifted it half an inch and let it fall free onto a solid plank. It received one and three quarter

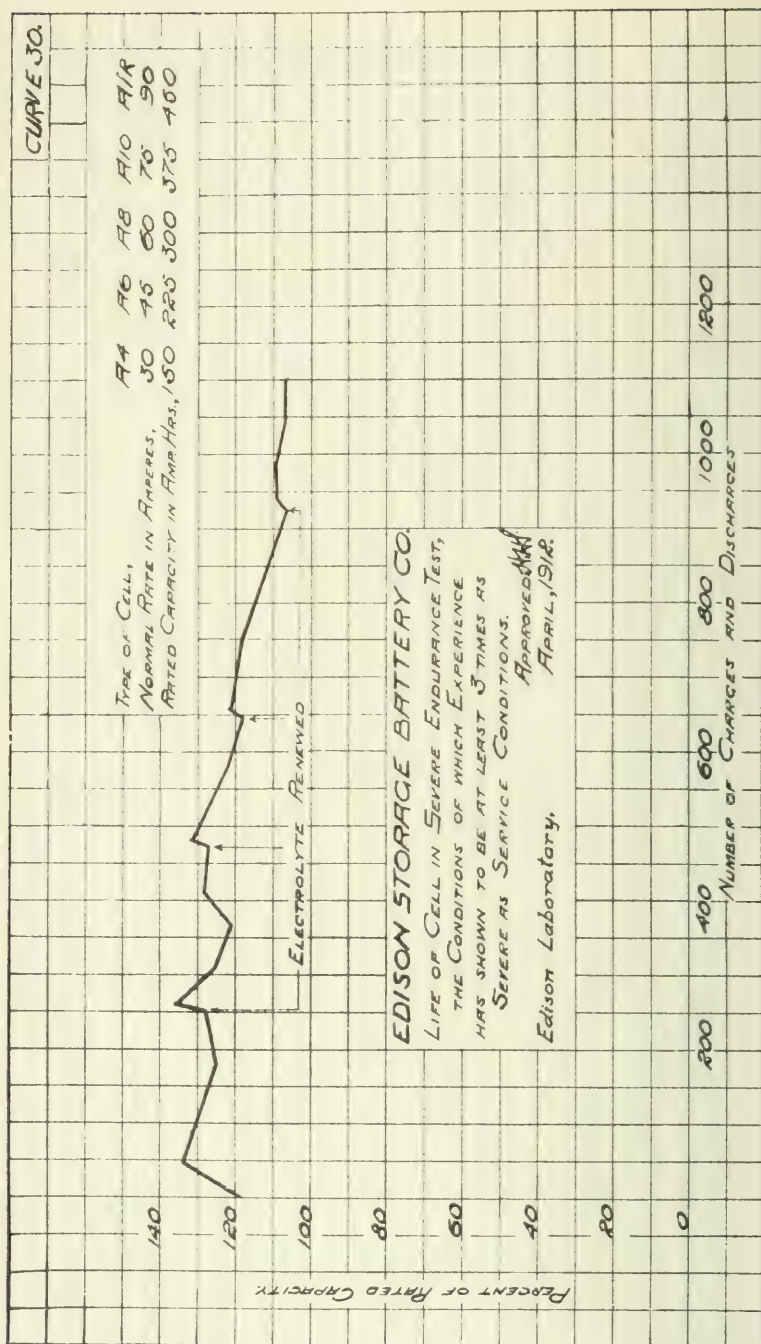


FIG. 3.

million such jolts. Electrically it proved to be as good as before, and when the can was removed for inspection it was found to be all right mechanically.

Short circuiting has been found to subject the battery to rather severe strains, and yet it has stood up under repeated subjection to this treatment. An A4 cell, whose normal rate is 30 amperes, was short-circuited nine times through a 600-ampere ammeter shunt. The needle each time remained above 500 for a few seconds and then slowly dropped. The first four of these showed a successive increase in the average current of the discharge, and the other five gave approximately the same curve as the fourth. A comparison of previous and subsequent normal discharges showed practically no difference. Discharges at six times normal rate, however, showed an improvement in voltage after the short-circuits. This cell was later taken apart and found to be in perfect condition. There was apparently not the slightest tendency toward buckling of the plates.

Last spring a prominent consulting engineer working on the electrification of mines said, "There is one thing I am especially afraid of when it comes to putting storage batteries on mining locomotives. Time and again I have seen drivers of these machines, in order to avoid a collision, swing the controller to full reverse while going full speed ahead. The motors are built to stand it, but how about the battery?" He was assured that the battery was good for worse than that, but he seemed incredulous and asked that a motor and battery be set up to try it out. "How would it do," he was asked, "to discharge a cell at normal rate and every fifteen minutes subject it to a dead short-circuit for three minutes?" This he agreed was far worse treatment than would ever be given in practice, so the test was made in his presence. The discharge lasted for two hours, during which time the cell was short-circuited seven times by means of a short piece of $\frac{3}{8}$ -inch copper rod. The voltage recovered quickly after the short circuit was removed in each case, and normal discharges before and after showed no change in characteristics. He was satisfied on that point.

Much has been made of the effect of temperature upon the Edison battery. Little need be said of the effect of high temperature, for the Edison battery will stand more heat than any other known type. During the short-circuit tests I have mentioned, the temperature rose to the boiling point of the electrolyte, about 220 deg. F. A limit of temperature is recommended for ordinary practice, because it will insure best results, but an occasional heating is not serious. The battery that was in a car utterly destroyed by fire some time ago, had its electrolyte boiled away and its rubber parts melted, but when these were replaced the battery worked as well as ever, delivering 28% above its rated number of ampere hours.

Storage batteries are sensitive to extreme cold, and this is es-

pecially true of the alkaline type. Below a certain critical temperature of electrolyte, which varies with the rate of discharge, very little capacity can be obtained, though it is not dissipated, for on warming the battery, the balance of its full capacity may be withdrawn. While this is true, there is no excuse in any climate for ever allowing the battery to get below the critical temperature. It has been proven beyond question that if the battery be housed in winter so that the circulation of air about the cells is prevented, and so that the air in the compartment will not be changed, no trouble will be experienced in the very severest cold, for still air is one of the best of heat insulators. It is a simple matter to construct a tight compartment, and I will quote one or two instances in which customers in northern climates have found it perfectly practical.

Perhaps one of the most severe cases was that of a car-lighting battery on the Illinois Central Railroad last winter. The battery was housed beneath the car in a sheet-steel compartment made proof against air currents in or out, but with wind space all around the compartment itself. The car was run during six weeks of the severest weather without any battery trouble. During this time there was a period of eleven days in which the temperature reached 42 deg. below zero and averaged 32 deg. below. A recording thermometer was placed in the compartment on the trip, and showed that the temperature *within the compartment* reached a minimum 8 deg. below zero, and yet the battery remained warm enough to operate with perfect satisfaction. On another trip the train was stalled in a snow bank for sixteen hours, during which time it was necessary to have light continuously. The battery was called on as long as the lights were bright enough to be useful, and it discharged 255 ampere-hours or 85% of its rating—a remarkable performance even if the battery were fully charged when the train became stalled, which is doubtful.

Let us examine a severe instance in automobile work. A garage in Winnipeg, Manitoba, during the winter housed three trucks equipped with Edison battery. The garage operators advised us in January of the excellent record these cars had made and said, in part, "We might also add, that on account of the severe test which these trucks have been put to in the last two weeks, due to the very severe weather we have had, we will place here in Winnipeg, fifteen trucks by spring, as we are proving out every day that the electric truck with the Edison battery is the only truck which will stand the terrific winters such as we experience in Manitoba. We might say that this morning (January 10th) the thermometer registered 44 deg. below zero, and at the present writing the thermometer stands at 36 below, and the three trucks are running as usual." The owners of one of these trucks were communicated with directly; their reply follows:

"We are in receipt of your favor of the 27th of February, regarding the performance of Edison storage batteries on our De-

troit truck. This truck has been in use since early October and the batteries have given every satisfaction. We were informed that we would have trouble in cold weather due to the batteries freezing, but are glad to say we experienced no difficulty of any kind whatever.

"We had a spell of exceedingly cold weather early in January, during which the thermometer frequently registered 35 and 40 below zero. During that period we gave the batteries every opportunity to freeze up, deliberately leaving the truck for an hour or two at a time in front of the warehouse. The only difference in the performance of the truck which we noticed after these tests was that it was a little slower in getting away, *i. e.*, it would have to run possibly a block or two before getting up to its speed. Under the circumstances we have no hesitancy whatever in saying that our batteries are eminently satisfactory."

Now as to just ordinary every-day service, let us examine a few records.

Figure 4 shows the average discharge of 48 Type A6 cells after two years and ten months' service in an electric brougham. The rated capacity of this type of cell is 225 ampere-hours and here, after almost three years' service, we find it delivering 277 ampere-hours or 23% above its rating.

Figure 5 shows the discharge of a cell taken from the battery of a one-ton truck which for nearly four years has been in constant daily use traveling an average of 28 miles per day. The battery is of Type A4 rated at 150 ampere-hours. When new, this cell delivered 182 ampere-hours, or 121% of its rating; after three years and nine months' service it yielded 192.5 ampere-hours, or 128% of its rating. This was one of the first batteries put into commission.

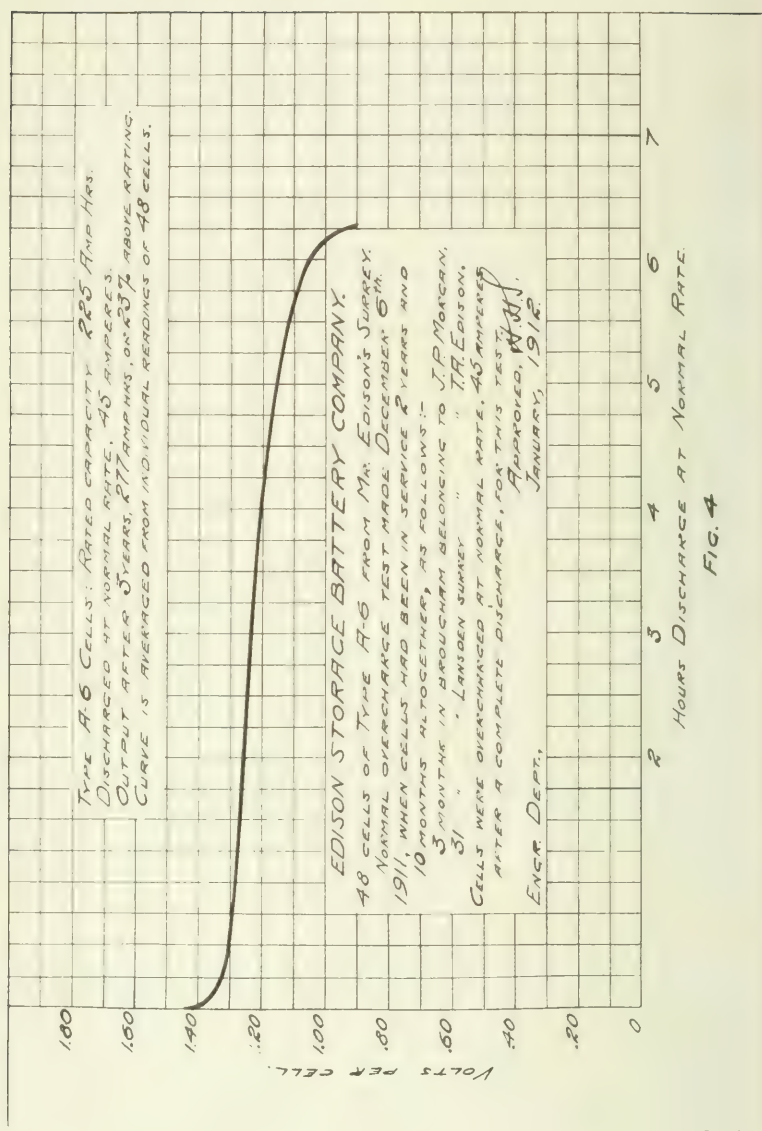
The curve of Fig. 6 shows the battery's durability under heavy-duty conditions. The test was made on the 60 cell A6 battery from a truck of the Metropolitan Opera Co., after nineteen months' service, including two opera seasons in which the truck was frequently overloaded, sometimes carrying 200% of its rated burden. The battery delivered 277 ampere-hours, or 123% of its rated capacity.

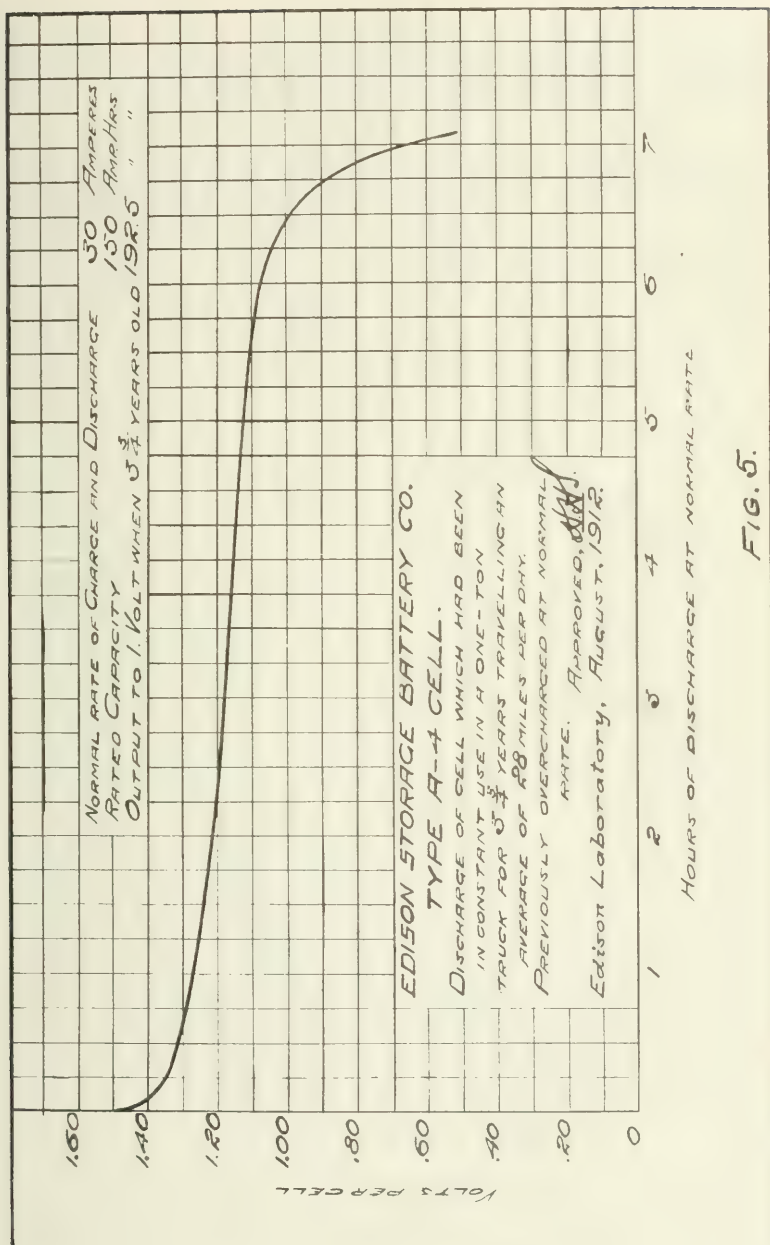
Many such performances might be shown if there were time for it.

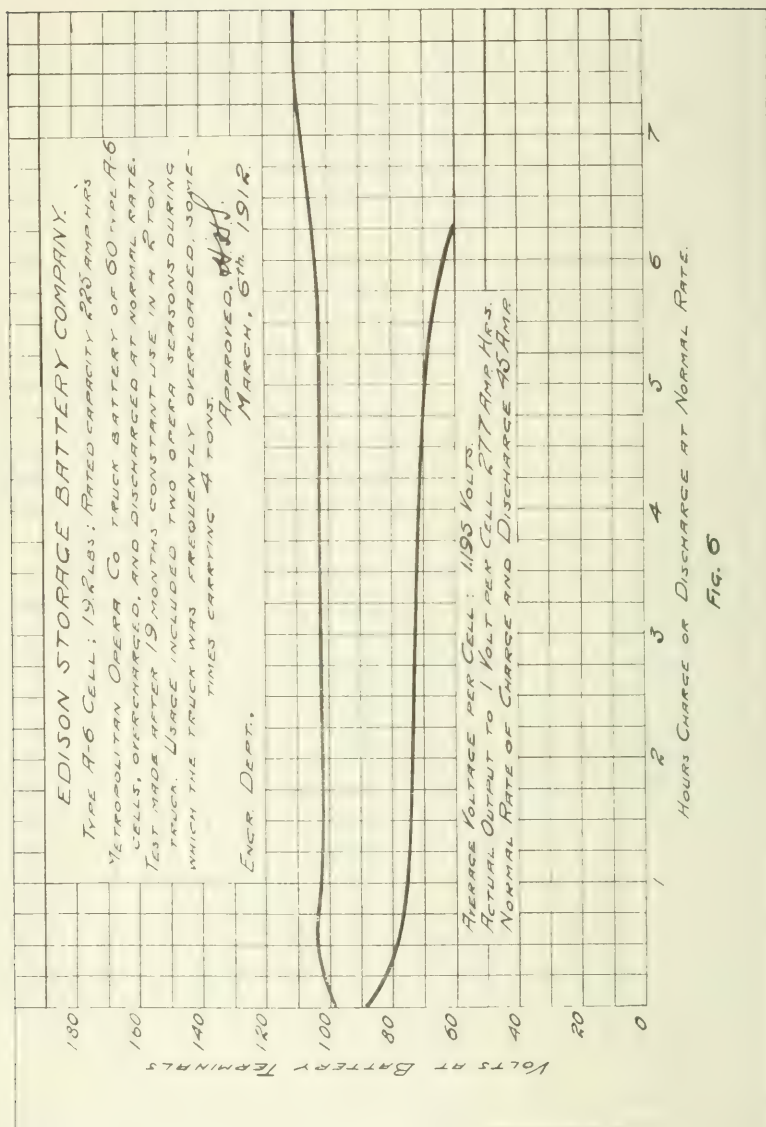
USES.

As has already been suggested, the Edison battery was originally intended to fill a need in automobile work, and the two general types were designed with the end in view of furnishing power for electric propulsion and for ignition and lighting in gas car practice. Its field of usefulness has been greatly enlarged and I will run over hurriedly some of its applications.

The ignition type of cell is put up in batteries of five each in steel boxes suitable for placing on the running board of car. These may be so chosen in size as to be suitable for ignition alone or to handle ignition, complete lighting and an electric horn. A set of







B4 cells which had operated a Klaxon horn for a full season on one charge was found, when taken out of service at the end of the season, to have a residual capacity of 55 ampere-hours on a discharge rate of 1 ampere. During the entire season the battery needed not one moment's attention; indeed, I doubt if the battery box was opened at all.

A company has recently been formed for the exchange of charged Edison auto lighting sets for discharged ones, along the lines that have been so admirably followed in gas lighting by the Prest-o-lite Company. Exchange stations are being established in cities throughout the country, and there is every promise that the great convenience of electric lighting for automobiles is going to secure for it immense popularity.

In the pleasure-car field, the battery as the source of energy has grown constantly in favor. In the middle and far West, electric automobiles are seen in large numbers and in the East their number is steadily increasing. The distinctive "electric" type is most frequently seen, though sometimes it is gotten away from, and now and then cars may be seen that closely resemble the gasoline model.

The street car offers an ever-broadening field and includes the larger interurban car, which in many cases will supplant steam on short-haul railroads. Recently a three-car storage battery train, equipped with multiple-unit control, was shipped to Cuba for the United Railways of Havana after its operation had first been demonstrated before representative engineers of this country. As far as I know, this is the first successful self-contained, multiple-unit, electric train ever built.

Electric busses are being used to a constantly increasing extent, and we hear the best of reports from those now in operation, especially from those operated by Carson, Pirie, Scott & Co. in Chicago.

The electric ambulance recommends itself because of its instant availability and unfailing reliability. The ability of the Edison battery to withstand being charged quickly and often, and being taken off charge and used or allowed to stand idle in any condition of charge or discharge, makes it particularly desirable in this service.

Thus far, the greatest field for the battery has been in the commercial truck service. Express companies have used them to a large extent. One of the largest companies operates hundreds of cars in different parts of the country equipped with Edison batteries.

The retail merchants have found the electric automobile invaluable for quick and reliable delivery. Some of them are using Edison battery cars in large fleets.

Large wholesalers are also fast realizing the advantages of the electric automobile in the city service.

Experiments are now being made with a light delivery wagon in an effort to place the automobile within the means of the corner

grocer and butcher. This wagon is propelled by a twenty-volt motor of special design. It will climb the steepest grade, requiring at times 300 amperes. The Edison battery has made such a vehicle possible. The battery is under the driver's seat.

Warehouse, dock, and baggage trucks have found a ready market. The saving in time and labor effected by an electric baggage truck may readily be appreciated when one sees the enormous load that may be handled by one man.

The storage battery mining locomotive is rapidly coming into its own. In many instances these locomotives are arranged to operate on the battery within the mine, and on an overhead trolley system when outside.

A more recent application of the battery is its use in the navy for gun firing and sight lighting. The standard set for this use consists of 10 B2 cells enclosed in a metal container in which they are imbedded in a protective insulating material. The Edison battery withstands without injury the severe concussion of the gun chamber, and this, coupled with the beneficial effect of the potash upon steel—preventing instead of causing corrosion—has secured for it a firm hold upon this service.

House lighting in localities isolated from central stations offers a big field that is just being developed.

DISCUSSION OF THE PAPERS BY MESSRS. WOODBRIDGE AND SMITH.

Ernest Lunn, M. W. S. E. (Chairman): After listening to the presentation of these papers, no one will question the statement that each of these gentlemen is an authority on the subject of storage batteries.

The purpose of the program committee, in having papers on the two types of storage batteries presented the same evening, was to show what a factor both types have come to be in solving some of our economic problems. Fifteen years ago, if a man made a large investment in storage batteries, he was considered either reckless or else very brave, but today investments are made with an understanding as to what may be expected of them. They are no longer looked upon as experiments and something to be feared. The demand for them is ever increasing, and the investment in this country runs up into millions of dollars.

The meeting is now open for discussion of these excellent papers.

P. B. Woodworth, M. W. S. E.: I want to express my pleasure and satisfaction in seeing this large audience, which indicates that we recognize the fact that the storage battery, while it is old, is today one of the things of interest and one of the things on which a great deal of engineering thought is being profitably expended. There is probably no line in which there is more activity than the one being discussed tonight. As a student and a listener, I want

to acknowledge that I know very little about the modern storage battery.

Mr. Lunn: It is quite evident that there is harmony between the lead and Edison storage battery people. I think it might be well for the government to make an investigation to find out if there is not a trust existing.

E. H. Freeman, M. W. S. E.: There is one feature in connection with the storage battery which is very important and which has been mentioned here, but which is very difficult to get into dollars and cents; namely, the use of the battery for stand-by service. I would like to hear some further discussion upon that topic from storage battery engineers.

D. Macrae: The remarks I will make apply more particularly, I think, to the lead battery and Mr. Woodbridge's paper. That paper refers particularly, as I understand it, to the use of batteries in railway service.

We are not so much in touch with batteries in railway work as we are in lighting and power service. For the latter purpose we find them very valuable; in fact, I do not know how we could very well get along without them. They are of economic value because power plants can be operated more efficiently; the boilers and generators can be operated to the limit of their full capacity, knowing that there is in readiness battery capacity to take care of any excessive load or to tide over any interruptions to the service, whether in the boiler room or in any part of the generating, transmission or converting equipment.

The first pages of the paper draw attention to the fact that a storage battery is different from a dynamo, and that it can be used as a reservoir of electricity.

A little further on it is pointed out that judgment must be exercised in deciding where a storage battery is economical. There is not much room there for discussion.

Following this is a description of a somewhat complicated regulating apparatus intended to make the battery take up and let go of the load as desired. This particular apparatus with carbon resistances is used for railroad work and we have had no experience with it here.

Referring to the question which Mr. Freeman asked about batteries for stand-by service, two or three months ago it was my privilege to prepare a short paper on some of the engineering features of stand-by batteries. From research I found that during the year 1911 in twelve direct current sub-stations there were thirty-three interruptions to the service. The time of interruption averaged from ten seconds to seventeen minutes, and the average time that the battery was on discharge before the rotaries were again put on the load was three and a half minutes. In that time the batteries picked up from 25% to 100% of the load that was

carried on the sub-station at the time of the interruption. Nearly all of the interruptions were caused by line transmission and machine troubles. One would suppose that the batteries were not doing much because they maintained the load for only three and a half minutes. Almost any kind of battery will do that much. It must not be forgotten, however, that, had there been no batteries to pick up that load (which was done almost immediately or quite so), there might have been a different story to tell. It might not have been three and a half minutes or it might not have been seventeen minutes. Consider, for a moment, a sub-station carrying perhaps 9,000 or 10,000 kw., dropping that entire load and throwing it onto other sub-stations that may at the time be carrying full load. If they also drop off from overload, troubles will multiply rapidly. Where storage batteries are a part of the distribution system, the trouble is nipped in the bud whether the load thrown on them be large or small, and a battery can bite off a very large load when required to do so.

Consider, also, if you please, a condition such as we had on our system this afternoon—a generator carrying a load of over 20,000 kw. Interrupt the excitation current of such a machine for five seconds or one-half second, and unless a battery of sufficient capacity is connected to the same excitation bus which will automatically supply the necessary excitation current, serious troubles may follow.

Carl Bussey: I notice Mr. Woodbridge has spoken of the depreciation of the battery being 8%. That is, 8% is to cover depreciation and maintenance, and I believe he said taxes. Is that correct?

T. Milton, M. W. S. E.: I was especially interested in Mr. Smith's reference to the ability of the Edison battery to stand short-circuits, and I would ask him if that is not due to the high internal resistance of the alkaline type of battery? I obtained the figures somewhere (I do not know how correct they are and I do not remember where I got them), that the short-circuit current of the alkaline type of battery is in the neighborhood of sixteen times the normal rate of discharge. I would like to say, in that connection, that the short-circuit current of a lead battery will vary anywhere from forty to sixty times the normal discharge rate. That is, if you would add resistance to the lead battery so that the internal resistance of the lead battery would equal the internal resistance of the alkaline battery, you could short-circuit it with the same current and with about the same effect.

I was much interested in the reference to the abuse that the alkaline battery would stand, particularly in connection with fire, and I would like to tell a little story of what happened in Station C of the San Francisco Gas & Electric Company during the big earthquake and fire. There were two lead-lined tank batteries that went

through that fire, one on the first floor and one on the second floor. The fire destroyed the whole building. The big steel girders that held the battery which was on the second floor crumpled and were bent double; they looked like so many reeds after the fire. The battery on the upper floor was dumped into the battery below. All of the wood casings of the tanks burned away and left the lead linings crumpled and looking like so many mail bags. The battery plates melted away from the bus bars and dropped down into the acid retained in the crumpled linings. The water in the electrolyte evaporated and left a syrupy electrolyte that was practically concentrated sulphuric acid. The battery remained in this condition for some days. When the fire was over, the batteries were dismantled and the plates piled up. Over one-half of these plates are today back in service in reassembled batteries. Note that this was no "bench test" fire, it was a real conflagration.

R. H. Rice, M. W. S. E.: As I see the use of the battery, it serves one of two purposes,—it is used either for emergency reserve only, or it is used in case of purchase of power for taking off the peak and reducing the payment on the maximum demand. If I am correctly informed, the Edison company in Chicago uses its batteries for emergency purposes only, and not in normal operation to reduce the peak. The street railway use of a battery would be for the purpose of reducing the maximum demands of power secured from the public supply company. I would like to hear some one speak on those two questions.

I would ask the authors of these papers whether or not the normal rating of the batteries is the same. It occurred to me that possibly the large overload capacity of the Edison cell may be due in some measure to a different method of rating. If that is so, it should be brought out.

The use of a battery for purposes of railway work is of very great interest, and I would ask Mr. Smith if he is at liberty to tell us the present status of the Illinois Central Railroad project, as the company was some time ago considering the adoption of storage batteries to propel cars.

G. W. Cravens: I desire to ask two questions. First, how do the relative weights per given capacity compare between the two types of cell? Second, has the Edison battery ever been used in similar conditions to those described for the lead battery in railway work?

A. Scheible, M. W. S. E.: Mr. Smith spoke of the heavy giving off of gases by the batteries when rapidly charged, but I did not notice any statement as to whether the gases or fumes given off are of a damaging nature.

A. S. Dennison: Mr. Smith, in speaking of the electrolyte, said that it was principally caustic potash with a certain additional hy-

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drate, the name of which I did not understand. I wish he would kindly repeat the name, and the purpose of that additional hydrate.

G. M. Wilcox: In discussing the effect of low temperatures upon the action of the Edison cell, I would ask Mr. Smith if there is not some definite temperature of the electrolyte itself, critical temperature, below which the cell ceases to act properly? The temperatures given, as I understand it, were for the air in the box around the cell and not for the electrolyte itself.

Mr. Woodbridge: One of the speakers has drawn attention to the fact that the two papers presented tonight discuss batteries as applied to two quite different fields and drew the conclusion that they were therefore confined to those two fields and did not overlap. As far as the lead battery is concerned, that conclusion, of course, is not true. My paper was necessarily confined to certain specific applications, that is, applications in which economical results were sought, and I necessarily confined myself to the larger applications of the storage battery. But the lead storage battery has been utilized in all of the applications where a storage battery is in use at all. There are a great many storage battery cars in operation with lead storage batteries and, as you know, the great majority of automobiles using batteries for propulsion, ignition, starting, and lighting employ the lead type. For train lighting and all those other applications, the lead battery has been extensively applied for many years. Those fields utilize properties and characteristics of the lead battery which I did not consider as coming under the head of *economy*.

The question of stand-by service from a storage battery is also one that is a little outside of the question of economy, but it has been brought up and possibly a few remarks on that subject might be in order. The early application of storage batteries to large electric lighting systems was made on the ground of economy, as a rule; that is, the battery was put in to take off the peaks and give an improved load factor. But in almost all cases it was found that after the batteries were installed the stand-by feature was of more value than the other, and the operation of the battery was gradually reduced to stand-by service. The operating companies found that it was of so much value as a stand-by source of energy that they got to operating it in that way and were unwilling to discharge it on the peak for fear they might be caught with the battery partly discharged when it would be of more importance to tide over some interruption; so that the stand-by service was gradually developed from the other. Then the type of battery was changed to meet the new conditions. Most of these lighting batteries were installed in localities where real estate was of extreme value, and where space was a vital factor in determining the character of the installation. The stand-by service was so intermittent in character, and the aggregate amount of work falling upon the

battery per annum was so small, that it was possible to design a thinner type of plate which would give satisfactory service in this kind of work, thus reducing the cost per unit of output and especially providing the maximum capacity in a limited floor space. All these considerations led to the adoption of the pasted type of plate for stand-by service in electric lighting work, so that the very large batteries which are now being installed are of this type rather than of the older Plante type.

An illustration of this kind of service along the lines which have already been brought about occurred some years ago when a battery was first installed in St. Paul for stand-by electric lighting service. It was not long after this was put in service that the alternating current power circuit was interrupted at the peak load. The battery was obliged to take the entire load for perhaps half or three-quarters of an hour, and the manager afterwards told me if they had been obliged to drop the load just at that time, when the people were getting ready to leave their offices, in all probability the offices would have been closed with the lights turned on, and there would have been great difficulty in picking up the load again; and if they had succeeded in doing this they would have had to carry this peak load all night. By keeping the battery on the line, people were reminded to turn off the light when they left their offices, and the battery was able to carry the load at the gradually lessening rate until other sources of power were put into service.

The question of depreciation is a very difficult one to discuss, because it is impossible to give a definite figure for battery depreciation which will cover all possible conditions. I mentioned 8% as covering depreciation, maintenance, taxes, and insurance. I should judge that 6% ought to cover depreciation and maintenance alone, and that the other 2% would cover the other items. Of course there may be some cases where it is good business to work a battery a great deal harder than normal and thus increase the item of depreciation. If it is a commercial proposition to do that, it will be done. In other cases it may be a commercial proposition to reduce the amount of work that a battery is obliged to do and thereby reduce the depreciation. But 6% ought to be a fair average figure. That figure should cover both maintenance and depreciation, owing to the fact that when renewals are made to the battery they are made with plates that are up-to-date, so that a battery does not finally become obsolete and have to be discarded on that account, as is the case with other types of machinery. The renewals keep the battery up-to-date and up to the present state of the art, so that the items of depreciation and maintenance are really combined into one item, and if the battery is maintained by renewal of plates from time to time, the item of depreciation is covered by the maintenance.

In regard to the difference in rating between the lead cell and
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the alkaline cell. The lead cell is usually rated on the eight-hour basis; that is, the normal rate has always been considered the eight-hour rate. In vehicle work, a five-hour rating or a four-hour rating has been adopted, although it has not been called the *normal* rate. I believe—and possibly Mr. Smith will confirm this understanding—that with the alkaline cell the five-hour rate is called the *normal*. So the term *normal rate* is somewhat ambiguous as applied to the two types of cells. In the lead cell it means the rate which the cell will give for eight hours; in the alkaline cell it means the rate which the cell will give for five hours.

As to the question of output per pound, in the ordinary types of portable cells the lead cell output is about ten watt-hours per pound. It is somewhat less than the figure given by Mr. Smith for the alkaline cell, which I believe he gave as from thirteen to sixteen watt-hours; but I understand that the figure sixteen is based on the uneconomical over-charge which is not recommended, so that the difference under normal conditions would be the difference between ten and thirteen watt-hours.

In certain kinds of service I believe that thirteen watt-hours can hardly be obtained under commercial conditions. That is, it means a voltage which is so low toward the end of discharge that it becomes not commercially useful. In regard to other characteristics of the lead cell. Take the question of ability to discharge at high rates. There was a time when the impression was quite general that the rate of discharge of a storage battery should be limited; otherwise the plates would buckle. That may have been true in the past, but it has not been true for many years. The rate of discharge of a lead battery may be anything that the circuit will stand. Of course, the question of short-circuiting a lead battery is somewhat different from the short-circuiting of an alkaline battery, because of the very much lower internal resistance of the lead battery and the very much greater current that can be obtained from it, but the danger is not in connection with the plates but with the outside circuit. A man, I understand, on one occasion dropped a monkey-wrench across the terminals of a cell and the monkey-wrench disappeared. Such things happen sometimes. It does not harm the plates, but it is dangerous to the external circuit.

Mr. Smith: As to the respective fields for the lead and Edison batteries, I will ask you to reserve decision for a period of possibly five years.

In regard to the short-circuiting current of the Edison battery being limited by the internal resistance, it is true that the short-circuiting current of the lead battery is much higher in comparison to the normal rate than it is in the case of the Edison battery. At the same time it is a short-circuit, and in many cases, as in the case of the mining locomotive cited, it is that short-circuiting current which counts, regardless of whether it is more or less. Short-circuit trouble will occur, and if the lead battery current is worse, so much

the worse for the battery. But, even so, I think that the comparison will still stand if it is made on the basis of a similar percentage of increase in current. It is not the instantaneous short-circuits altogether that are significant; it is the continued short-circuits throughout an entire discharge and for repeated successive discharges.

In regard to the case of a lead battery surviving, in part, a fire, I think that the comparison is still instructive.

There are two ways of reducing the peak loads in railway service. One is to employ, during the rush hours, a number of storage battery cars which have been charged during the non-rush hours. To answer the question bearing on this point, I would say that the Edison battery will enter into that field of peak load reduction, but it has not, up to the present time, been considered in connection with the other method, described by Mr. Woodbridge, of assuming the peak at the power station.

In regard to the rating, I rather inferred from Mr. Rice's remarks that he meant ampere-hour rating rather than current rating. The reason for the Edison battery rating is that the current rate was decided upon more or less arbitrarily as striking the best balance between maximum efficiency and maximum output, and then, for convenience, the ampere-hour rating was taken at the five-hour rate, which was in accord with vehicle battery practice.

I might say that the life curves of the two batteries are quite different in their general trend. The Edison battery increases in its output during possibly two years of its life, whereas the lead battery increases for a very short time and then declines.

In regard to whether the Illinois Central Railroad Company has contemplated putting in any storage battery service, this brings to mind an article I read a short time ago in connection with the electrification of the New York, New Haven & Hartford road. Word came to some Chicago newspaper that the New Haven road was contemplating increasing its electrification to New Haven, and the paper remarked, "Will somebody please stop this misguided railroad before it is too late? We know that electrification does not pay; the Illinois Central Railroad says it is impossible."

In regard to storage battery propulsion being applied to the Chicago problem, I will intimate this,—that the Smoke Department has gone to some extent into the matter of storage battery electrification in the terminals, as a possible means of avoiding the very complicated third rail system that would be necessary in the big yards in Chicago.

In regard to the relative weights, the stated output of ten watt-hours per pound of lead battery, I believe, is based on a maximum charge, as is the sixteen and one-half watt-hours of the Edison battery.

As to the full capacity being useful in an Edison battery up to thirteen and one-half watt-hours per pound, it is a fact that in certain railway installations the battery has been so chosen as to de-

liver only a fraction of its rated capacity, but this has been done not by accident but by design, and it involves a number of problems, which are too lengthy to go into at the present time.

A question has been asked, in regard to the Edison battery being used in a service similar to the one described in Mr. Woodbridge's paper, but, as I have already said, it has not been applied to that work.

In regard to the nature of the gases given off by the Edison battery during charge, they are hydrogen and oxygen, of course, and they carry with them a small percentage of the electrolyte. That is, minute bubbles of gas are given off and particles of electrolyte cling to them. It is the same in this respect with the Edison as it is with the lead battery. In one case the vapor is alkaline, and in the other case it is acid. It is only a question which is the more damaging, and I would say that the gases given off in the charging of the alkaline battery are not objectionable to the human lungs. The forming room of the Edison storage battery is perfectly free from any noxious odor, and, as you all know, the effect of an alkali upon most metals is preservative rather than corrosive.

The electrolyte of the Edison battery is mainly caustic potash, and the other ingredient is a small amount of lithium hydrate. Little is known of the actual effect of this material, and the process by which the effect is arrived at. It seems to accomplish a cementation of the positive material. We have found that the cells in the early days that were put up with caustic potash alone, deteriorated very rapidly in the positive plate, and when the action of lithium was discovered, this deterioration was overcome.

In regard to the cold affecting the battery; there is a critical temperature which varies with the density (and that means the age) of the electrolyte, and also it varies greatly with the service to which the battery is put. The higher the rate, the higher the critical point. But on the average it is between 40 and 50 deg. F., normal working. Yet it is misleading to make that statement, because the thought naturally suggests itself that 40 or 50 deg. is a temperature which is very readily attained. But that is not so, as is proven by the instances already quoted, where the battery has worked satisfactorily at a temperature almost that much below zero.

The Electrical Testing Laboratories of New York took a 60 cell standard vehicle type battery and enclosed it in a box which was commercially tight; it was not absolutely air tight, but was comparable with what might be obtained in vehicle practice. With the electrolyte at a temperature of 90 deg., the battery was put into a room where a temperature of 5 deg. above zero was maintained, and it took three days for the battery, remaining idle, to be brought down to the room temperature. So that in ordinary service it will take a lot of cold covering long periods to get the battery temperature down, especially when the battery is working.

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Annual Meeting, January 8, 1913.

The 43rd Annual Meeting of the Society (No. 806) was held Wednesday evening, January 8, 1913, in the Louis XVI Banquet Room of the Hotel Sherman, Chicago. The annual dinner preceded the meeting, with an attendance of 169, convening at 6:30 p. m.

At the speakers' table were President W. C. Armstrong, President-elect Albert Reichmann, Judge C. S. Cutting, Dr. Emory R. Johnson, of Philadelphia, Mr. Charles H. Wacker, of the Chicago Plan Commission, Dr. Clarence B. Strouse, of Virginia, Vice-Presidents A. Bement, B. E. Grant, and J. F. Hayford, Treasurer-elect C. R. Dart, Trustees F. E. Davidson, Ernest McCullough and J. G. Giaver, Past-Presidents W. L. Abbott, B. J. Arnold, W. H. Finley, Onward Bates, O. P. Chamberlain, and Andrews Allen.

President Armstrong called the meeting to order and asked the Secretary for his report (printed elsewhere). He then made his address on retiring from the presidency, and then introduced President-elect Albert Reichmann, to whom he turned over the duties of the President. Mr. Reichmann made his address, and then introduced Judge Cutting as toastmaster, who performed the duties connected therewith in an admirable manner.

Dr. Emory R. Johnson was introduced, who read his paper on Panama Traffic and Tolls, wherein he showed the unwisdom of exempting from the canal tolls the shipping engaged in the United States coastwise transportation. This is printed elsewhere in the *Journal*. Mr. Charles H. Wacker was then introduced, who read his paper on The Chicago Plan, which was illustrated by lantern slides, and was much appreciated by all present.

Dr. Strouse followed with some witty and entertaining remarks.

The meeting adjourned about 11 p. m.

Excursions January 8th and 9th, 1913.

The special Entertainment Committee—Messrs. B. F. Affleck, H. J. Burt, and E. S. Nethercut, arranged for an excursion for Wednesday afternoon, January 8, 1913, to the new Northwest Station of the Commonwealth Edison Company. Through the courtesy of the C. & N. W. Ry. Co., a special train was provided, which conveyed about 105 visitors to near Avondale, where there is track connection with the private track of the Commonwealth Edison Co., over which the cars were hauled by an electric locomotive to the plant. The visitors were shown the plant, which is of considerable magnitude, containing as it does now two turbo-generators, each of 20,000 kw. capacity, and which are in operation. After inspecting the plant, a very pleasant buffet-lunch was served, and the visitors were then conveyed back to the city, arriving there before 5 p. m.

The next day, Thursday afternoon, an excursion was made by special train over the C. & A. R. R. to Argo, Illinois, where the immense plant of the Corn Products Refining Co. is located, and where much of interest was shown the visitors, who numbered about 125. The excursion party returned to the city about 5 p. m.

In the evening there was a special meeting (No. 807) in the Society's rooms—a Smoker—when entertainment in the way of songs, music, speeches, etc., made the evening highly appreciated.

The meeting adjourned about 10:30 p. m.

Extra Meeting, January 13, 1913.

An extra meeting of the Society (No. 808), the Bridge and Structural Section, was held in the Society Rooms Monday evening, January 13, 1913. The meeting was called to order about 8:20 p. m., with President Reichmann presiding (in the absence of Chairman Davidson), and about 40 members and guests in attendance.

January, 1913

The minutes of the meeting of December 9, 1912, were read and approved. The Secretary stated that this was the annual meeting of the Section, and that the election of members of the Executive Committee was in order. Nominations for this committee had been made at the preceding meeting.

The result of the balloting showed that
Mr. I. F. Stern was elected Chairman
Mr. J. H. Prior was elected Vice-Chairman

and Messrs. J. G. Kreer and Lee Jutton were elected members of the Executive Committee. Mr. F. E. Davidson, the retiring Chairman, is also a member of this committee.

Mr. Stern having assumed the chairmanship, after a few pertinent remarks, introduced to the meeting Mr. A. C. Janni, of St. Louis, the author of the paper for the evening, "Design of an Arch System by the Method of the Ellipse of Elasticity." After first showing some lantern slide views of the Kingshighway concrete arch bridge in St. Louis, the speaker proceeded to explain the principles of the ellipse of elasticity. Discussion followed from Messrs. McCullough, Reichmann, and Stern, with explanations and replies from Mr. Janni.

The Secretary offered a motion of a vote of thanks to Mr. Janni, which was passed.

Meeting adjourned at 10 p. m.

Extra Meeting, January 20, 1913.

An extra meeting (No. 809) of the Society, the Hydraulic, Sanitary and Municipal Section's annual meeting, was held Monday evening, January 20, 1913.

The meeting was called to order at 8:30 p. m., Mr. Langdon Pearse presiding, and about 85 members and guests in attendance.

A ticket was presented for the new Executive Committee as follows:

Mr. Langdon Pearse, Chairman,
Mr. W. D. Gerber, Vice-Chairman,
Mr. W. T. Barnes, Member of Committee,
Mr. G. C. D. Lenth, Member of Committee,
Mr. C. B. Burdick, Past-Chairman, as holdover.

This ticket was accepted by a *viva voce* vote, and, on motion, the nominees were duly elected by the same method. There was no other business brought before the meeting.

The Chairman introduced Mr. Edward N. Hines, one of the County Commissioners of Detroit, Mich., who gave an interesting talk on "Concrete Roads as built in Wayne County, Mich." Some moving pictures were shown in illustration of the talk. Discussion followed from Mr. Wilson of Mason City, Iowa, Mr. McCullough of Fond du Lac, Wis., Mr. Kuelling of Milwaukee, Mr. W. S. Shields, and others.

Meeting adjourned at 10:30 p. m.

J. H. WARDER, Secretary.

ANNUAL REPORTS.

SECRETARY'S REPORT.

Chicago, January 8, 1913.

To the Board of Direction, Western Society of Engineers, Chicago.

Gentlemen: Of the affairs of the Society for the past year, there is but little to report different from a year ago. A change was made, in that the meetings have been held on Monday evenings instead of Wednesday evenings, but this has not occasioned, as far as noticed, any change in the attendance at the meetings. The general attendance, however, has seemed

to your Secretary as not being what it should be with a resident membership of over 600.

The use of the rooms and library is more general, as it is becoming better known as a place for study and research. The library space has been increased by the lease of a room known on the plat of the building as No. 1736, having about 315 square feet of floor space. In this has been placed substantial library and reading tables, with chairs and a number of book cases, and to which have been transferred many books for reference and study. The annual rental of this additional room is \$390.00.

The growth of the Society has been about the same as last year. The total number of applications of all grades was 113, but this includes a considerable number of transfers which, while adding to the revenue and corporate membership, do not add to the net membership. There were nine applications for Student Member grade this past year, the most of them coming from the University of Illinois. The actual increase in membership for the year has been materially lessened by death (ten members), resignations, and those dropped for non-payment of dues.

The total membership December 31, 1912, was as follows:

	Resident.	Non-Resident.	Total.
Honorary Members	1	2	3
Members	448	318	766
Associate Members	130	81	211
Junior Members	72	51	123
Affiliated Members	42	8	50
Student Members	3	7	10
Total.....	696	467	1163

During 1912 the following ten members have been taken from us by death:

William H. Harris, Chicago.....	January 31, 1912
John S. Metcalf, Chicago.....	March 4, 1912
James P. Coleman, Chicago.....	April 13, 1912
W. K. Means, Manitowoc, Wis.....	April 17, 1912
Charles W. Brown, Jacksonville, Ill.....	May 25, 1912
Charles E. DeCrow, Chicago.....	June 17, 1912
Horace E. Horton, Chicago.....	July 29, 1912
Charles L. Harrison, New York.....	September 15, 1912
Henry F. White, Chicago.....	October 28, 1912
Francis H. Bainbridge, Winnetka, Ill.....	December 3, 1912

The Society (including the Sections) held thirty-eight meetings during 1912 on Monday evenings, the Annual Meeting with two excursions, January 10th and 11th, 1912; nine regular meetings, on the first Monday of each month, except July and August; and twenty-seven extra meetings on other Monday evenings, including one "Ladies' Night."

List of Meetings Held in 1912.

- Monday, Jan. 8th. (No. 768) Extra meeting—Annual Meeting, Bridge and Structural Section. Mr. R. Modjeski read his paper on "*The Celilo Bridge*" over the Columbia River.
- Wednesday, Jan. 10. (No. 769) Annual Meeting and Dinner.
- Thursday, Jan. 11. (No. 770) Second Session of Annual Meeting. A Smoker, with illustrated address from Mr. Frost of Yerkes Observatory, Williams Bay, Ill., "*The Movements of the Fixed Stars.*"
- Monday, Jan. 15. (No. 771) Extra Meeting—Annual Meeting of the Hydraulic, Sanitary and Municipal Section. Mr. L. K. Sherman presented his paper on "*Run-Off from Sewered Areas.*"

January, 1913

- Monday, Jan. 22. (No. 772) Extra and Joint Meeting of the Electrical Section W. S. E. and Chicago Section A. I. E. E. Mr. Robert J. Young gave an illustrated lecture on "*The Prevention of Industrial Accidents.*"
- Monday, Jan. 29. (No. 773) Extra Meeting. Mr. C. M. Strieby gave an illustrated talk on "*An Automobile Factory in Action.*"
- Monday, Feb. 5. (No. 774) Regular Meeting. Lieut. Col. George A. Zinn, U. S. Engineer, read a paper on "*The Chicago Water-Ways Improvements and their Relation to Transportation.*"
- Monday, Feb. 12. (No. 775) Extra Meeting. The Bridge and Structural Section. Topical Discussion, "*Assembling and Reaming.*"
- Monday, Feb. 19. (No. 776) Extra Meeting. Mr. Linn White and Mr. A. C. Schrader, "*The Wearing Surface for Boulevards and Streets of Light Traffic.*"
- Monday, Feb. 26. No formal meeting. Mr. D. W. Roper described the thawing out of frozen water pipes and hydrants by aid of an electric current.
- Monday, March 4. (No. 777) Regular Meeting. Mr. Edwin D. Dreyfus presented his paper, "*New Developments in Steam Turbine Engineering.*"
- Monday, March 11. (No. 778) Extra Meeting. Bridge and Structural Section. Topical Discussion, "*Light Compression Members.*"
- Monday, March 18. (No. 779) Extra Meeting. Mr. W. H. Finley addressed the meeting on "*Waterproofing of Engineering Structures.*"
- Monday, March 25. (No. 780) Extra Meeting. Joint Meeting of the Electrical Section W. S. E. and Chicago Section A. I. E. E. Mr. H. F. Smith presented "*Notes on Producer Gas Power,*" with illustrations.
- Monday, April 1. (No. 781) Regular Meeting. Mr. Onward Bates presented his paper on "*Arbitration.*"
- Monday, April 8. (No. 782) Extra Meeting. Bridge and Structural Section. Messrs. F. A. Randall, Edwin Hancock, W. L. Cowles, and F. E. Davidson addressed the meeting on "*The Bearing Power of the Subsoil of Chicago.*"
- Monday, April 15. (No. 783) Extra Meeting. Hydraulic, Sanitary and Municipal Section. Topical Discussion, "*The Relation of the State to the Practice of Engineering.*"
- Monday, April 22. (No. 784) Extra Meeting. Joint Meeting, Electrical Section, W. S. E. and Chicago Section, A. I. E. E. Mr. Burke Smith read his paper on "*The Depreciation and Replacement of Growing Telephone Plants.*"
- Monday, May 6. (No. 785) Regular Meeting. Mr. E. L. Lundgren gave a talk on "*The Philippines.*"
- Monday, May 13. (No. 786) Extra Meeting. "Ladies' Night." Mr. W. R. Patterson gave an illustrated talk "*A Trip Around and About the United States.*"
- Monday, June 3. (No. 787) Regular Meeting. Prof. H. H. Stoek presented his paper, "*The Geology, Mining and Preparation of Anthracite Coal,*" with illustrations.
- Monday, June 10. (No. 788) Extra Meeting. Bridge and Structural Section. Mr. D. B. Luten presented his paper on "*Arch Design; Specialization and Patents.*"
- Monday, June 17. (No. 789) Extra Meeting. Hydraulic, Sanitary and Municipal Section. Prof. D. W. Mead addressed the meeting, with lantern slide illustrations, on "*The Cause of Floods and the Estimate of their Intensity.*"

- Monday, Sept. 2. (No. 790) Regular Meeting. Mr. E. L. Corthell's paper, "*Brief Review of Engineering Practice and Personal Experience in Latin America, 1880-1912*," read by the Secretary.
- Monday, Sept. 9. (No. 791) Extra Meeting. Bridge and Structural Section. Prof. O. H. Basquin presented his paper on "*The Circular Diagram of Stress and its Application to the Theory of Internal Friction*."
- Monday, Sept. 16. (No. 792) Extra Meeting. Mr. S. A. Greeley presented his paper on "*Municipal Refuse Collection*."
- Monday, Sept. 23. (No. 793) Extra Meeting. Mr. Joseph Harrington presented his paper on "*Furnace Efficiency*."
- Monday, Oct. 7. (No. 794) Extra Meeting. Bridge and Structural Section. Prof. Albert Smith presented his paper on "*Wind Pressure on Buildings*."
- Monday, Oct. 14. (No. 795) Extra Meeting. Bridge and Structural Section. Messrs. F. E. Davidson and Andrews Allen gave a talk on "*Small Industrial Plants*."
- Monday, Oct. 21. (No. 796) Extra Meeting. Hydraulic, Sanitary and Municipal Section. Mr. Geo. W. Fuller addressed the meeting on "*The Permissible Limits of Sewage Dilution*."
- Monday, October 28. (No. 797) Extra Meeting. Joint Meeting of the Electrical Section W. S. E. and the Chicago Section A. I. E. E. Dr. C. P. Steinmetz gave an address on "*Some Problems in Electrical Engineering*."
- Monday, Nov. 4. (No. 798) Regular Meeting. Mr. Osborn Monnett presented his paper, "*New Methods of Approaching the Smoke Problem*."
- Monday, Nov. 11. (No. 799) Extra Meeting. Bridge and Structural Section. Mr. E. S. Pennebaker presented his paper "*Economical Design for a Timber Cotton Shed*."
- Monday, Nov. 18. (No. 800) Extra Meeting. Mr. Edward T. Perkins addressed the meeting on "*The National Aspect of the Reclamation of Swamp and Overflowed Lands*."
- Monday, Nov. 25. (No. 801) Extra Meeting. Joint Meeting of Electrical Section W. S. E. and Chicago Section A. I. E. E. Messrs. J. L. Woodbridge and H. H. Smith presented papers on The Storage Battery.
- Monday, Dec. 2. (No. 802) Regular Meeting. Mr. Richard T. Fox presented his paper on "*Street Cleaning in Down-Town Chicago*."
- Monday, Dec. 9. (No. 803) Extra Meeting. Bridge and Structural Section. Prof. O. H. Basquin presented his paper on "*Columns*."
- Monday, Dec. 16. (No. 804) Extra Meeting. Prof. F. R. Moulton, University of Chicago, addressed the meeting on "*Other Worlds Than Ours*."
- Monday, Dec. 23. (No. 805) Extra Meeting. Joint Meeting of the Electrical Section W. S. E. and Chicago Section A. I. E. E. Mr. W. L. Abbott read his paper on "*The Commonwealth Edison Company's Northwest Station*."

During the past year, 1912, the *Journal* has been issued regularly as a monthly publication, except in July and August. These ten numbers aggregate 1054 pages of reading matter.

The finances of the Society are in healthy condition, as will be shown in the annual report of the Treasurer. It may be here stated that the cash assets of the Society, interest-bearing investment, and cash in bank, amounted to \$12,181.41 at the end of 1912, which is an increase of \$700.33 over that of

January, 1913

a year ago. The business of the Society, receipts and expenditures for the year, amounts to above \$20,000.

Respectfully submitted,

J. H. WARDER, Secretary.

LIBRARIAN'S REPORT.

January 8, 1913.

To the Board of Direction, Western Society of Engineers,

Gentlemen: The Librarian begs to submit the following report on the library of the Society, for 1912:

Total accessions to the library December 31, 1912.....	8968
Additions to library during 1912.....	576

Classified as follows:

Number of bound books—gifts and exchanges.....	382
Number of volumes bound by the Society.....	155
Number of books purchased.....	39
	576

Charges against the library account:

Bookbinding	\$125.40
Book purchases	106.36
Sundries	2.75
	\$234.51
Charged to Furniture and Fixtures, for 1912.....	190.47

This does not include the cost of services.

Very respectfully submitted,

J. H. WARDER, Librarian.

TREASURER'S REPORT FOR THE YEAR ENDING DEC. 31ST, 1912.

Jan. 2nd, 1913.

To the Board of Direction, Western Society of Engineers, Chicago, Ill.

Gentlemen: I respectfully submit herewith, a statement of the Treasurer's account for the year ending Dec. 31st, 1912, as follows:

CASH STATEMENT.

Jan. 1st, 1912, cash in bank subject to check.....\$ 1,758.08

RECEIPTS.

Dues	\$12,068.19
Entrance Fees	1,036.00
Subscription to Journal	285.10
Advertising	2,286.22
Sales Journal	251.90
Interest	545.13
Journal Account	77.20
Library Account	95.09
House Expense	584.23
Stationery, Postage and Exchange	48.11
General Printing	73.40
Investments	1,000.00
Bound Journal	97.50
Services	33.80
Medal Account	25.00
Badge Pins	255.00
	\$18,761.87
	\$20,519.95

EXPENDITURES.

Dues	\$ 6.25	
Advertising	164.00	
Journal Account	4,254.98	
Library Account	338.15	
House Expense	3,690.28	
Stationery, Postage & Exchange	902.64	
General Printing	716.57	
Furniture & Fixtures	194.97	
Chanute Medal Fund	331.91	
Investments	3,072.50	
Bound Journal	78.20	
Medal Account	13.05	
Badge Pins	114.15	
Services	6,160.89	
		\$20,038.54
Dec. 31st, 1912, cash in bank subject to check.....		481.41
		\$20,519.95

SUMMARY.

Statement Jan. 1st, 1912.		
To credit of Western Society of Engineers.....	\$ 9,182.08	
Chanute Medal Fund	1,299.00	
Arnold Fund	1,000.00	
		\$11,481.08
Investments	9,723.00	
Cash	1,758.08	
		\$11,481.08

Statement Jan. 1st, 1913.		
To credit of Western Society of Engineers.....	\$ 9,882.41	
Chanute Medal Fund	1,299.00	
Arnold Fund	1,000.00	
		\$12,181.41
Investments	11,700.00	
Cash	481.41	
		\$12,181.41

Respectfully yours,
ALBERT REICHMANN, Treasurer.

REPORT OF THE JUDGES OF ELECTION.

January 3, 1913.

The undersigned Judges of Election, having canvassed the ballots cast for officers of the Western Society of Engineers for the year 1913, have the honor to report as follows:

Total number of votes cast.....	357
Number of ballots rejected as irregular.....	9
Number of ballots rejected as not qualified to vote on account of non-payment of dues	2
	11
Total number of ballots counted	346
Number of votes cast for President:	
Albert Reichmann	333
Number of votes cast for First Vice-President:	
A. Bement	321
Number of votes cast for Second Vice-President:	
B. E. Grant	195
I. L. Simmons	136

January, 1913

Number of votes cast for Third Vice-President:

J. F. Hayford	193
M. B. Wells	130

Number of votes cast for Trustee for three years:

F. E. Davidson	324
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Number of votes cast for Treasurer:

C. R. Dart	332
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Respectfully submitted,

HIERO B. HERR,
R. F. SCHUCHARDT,
WM. ARTINGSTALL,

Judges of Election.

REPORT ON THE CHANUTE MEDAL AWARDS.

December 2, 1912.

To the Honorable Board of Direction, Western Society of Engineers,

Gentlemen: Your committee appointed to examine the papers presented during the year 1911, beg leave to report that they have carefully gone over the various papers presented, and recommend that the three medals for that year be awarded as follows:

1. For the best paper in Civil Engineering, to Mr. John Ericson, for his paper on "Investigations of Flow in Brick Lined Conduits," presented October, 1911.

2. For the best paper in Mechanical Engineering, to Mr. H. Gansslen, for his paper on "Ball Bearings for Heavy Loads," presented November, 1911.

3. For the best paper in Electrical Engineering, to Mr. Chas. F. Burgess, for his paper on "Electrolytic Corrosion of Iron in Concrete," presented May, 1911.

All of which is respectfully submitted,

J. W. ALVORD, Chairman;
A. L. RICE,
P. JUNKERSFELD,

Committee.

THE OCTAVE CHANUTE MEDAL.

In 1901 the late Octave Chanut presented to the Western Society of Engineers a fund sufficient to defray the cost of four medals, to be awarded to members for the best papers presented before the Society during that year. At the following Annual Meeting Mr. Chanut, as retiring President of the Society, established and presented to the Society an endowment sufficient to provide, from the income, for the awarding of three medals annually, to members, for the best papers within the subjects of civil, mechanical and electrical engineering.

Until the present time the initial design of medal originally prepared has been employed for the various awards. By the year 1910, however, the income from the endowment had accumulated to a sufficient amount to make feasible the establishment of a permanent design. To carry out this purpose a committee, composed of Messrs. C. L. Strobel, Andrews Allen, and A. Bement, under the chairmanship of the latter, was appointed by the Board of Direction of the Society. This committee made an extensive study of all phases of medal design and execution, conferring with many artists, designers, and engravers. One of the requirements insisted on by the committee was that the medals should be individual in character; that is, that the name of the recipient should appear upon it in the same style and manner as other wording.

The final achievement was executed by The Greenduck Company, medalists, of Chicago, assisted by Lou Wall Moore, who modeled a profile of Mr. Chanute. This medal is unique in its feature of individuality. Usually it is the custom for the name of the recipient to be engraved in a place left for that purpose. Thus the insertion of the engraved name does not harmonize with other features of the design, and the medal thereby loses character. But in the scheme finally developed, the recipient's name is struck at the same time the medal is made, and it becomes, in fact, a special medal, of which only one is made. Thus, each to whom an award is made receives a medal made especially for him, rather than one with his name engraved upon a general design.

Octave Chanute was born in Paris, France, February 18, 1832. He was six years of age when his family came to America to live, and his education was completed in New York. In 1849, at the age of 17, he began work on the Hudson River Railroad, and continued in the railroad business in various capacities for many years afterwards.

Soon after 1885 he became interested in wood preservation.

As long ago as 1874 Mr. Chanute was interested in aviation, but not until 1889, when he made Chicago his home, did he find time to devote himself seriously to the subject of aerial navigation. Two papers on the subject of aviation were presented by him to the Society—one on Gliding Experiments, October 20, 1897, and the other on Recent Progress in Aviation, October 20, 1909. It is an interesting fact that Mr. Chanute was awarded one of the medals for his paper on Recent Progress in Aviation, but as the award was made just about the time of his death, the medal was presented to his family.

Mr. Chanute became an Active Member of the Society July 12, 1869, was President in 1901, and was elected an Honorary Member January 5, 1909. He died at his home in Chicago, November 23, 1910.*

The awards of the Chanute medal thus far made are shown in the following:

Year.	Recipient.	Branch of Engineering.	Title of Paper.
1901	A. Bement	Mechanical Engineering	A Simple Method of Determining the Conditions of Combustion, with Suggestions on Working Furnaces.
	A. V. Abbott	Electrical Engineering	Electrical Oscillations of High Frequency.
	J. H. Spengler	Civil Engineering	Water Works System of Chicago.
	W. D. Pence	Civil Engineering	The Coefficient of Expansion of Concrete.
1902	J. W. Alvord	Civil Engineering	Sewage Purification Plants.
	R. E. Milligan	Mechanical Engineering	Mechanical Filtration.
	E. B. Ellicott	Electrical Engineering	Transmission of Fire Alarms.
1903	A. Marston	Civil Engineering	Sewage Disposal in Iowa.
	Storm Bull	Mechanical Engineering	The Use of Superheated Steam.
	E. Gonzenbach	Electrical Engineering	The Third Rail for High Speed Electric Service.
1904	W. A. Shaw	Civil Engineering	The Intercepting Sewers of Chicago.
	A. Bement	Mechanical Engineering	Some Boiler Performance with Chain Grate Stokers.
	Geo. A. Damon	Electrical Engineering	Opportunities in the Electrical Business.
1905	T. L. Condron	Civil Engineering	Strength of Reinforced Concrete.
	C. E. Sargent	Mechanical Engineering	The Prime Mover of the Future.
	C. H. Smoot	Electrical Engineering	Experimental Determination of Air-Gap Reluctance.
1906	G. H. Bremner	Civil Engineering	Areas of Waterways for Railroad Culverts and Bridges.
	W. L. Abbott	Mechanical Engineering	Some Characteristics of Coal as Affecting Performance with Steam Boilers.
	R. F. Schuchardt	Electrical Engineering	The Rotary Converter Sub-station.
1907	F. E. Turneure	Civil Engineering	Experimental Determination of Stresses in Web Plates and Stiffeners in Plate Girders.

*The memorial of Octave Chanute is published in the Journal of the Western Society of Engineers, Vol. XVI, No. 5, May, 1911.

	Walter T. Ray and Henry Kreisinger	Mechanical Engineering	The Nature of True Boiler Efficiency.
	D. W. Roper	Electrical Engineering	A Few Unusual Burnouts of Underground Cables.
1908	H. E. Horton	Civil Engineering	The Wrought Compressive Member for Bridge Trusses.
	A. N. Talbot	Mechanical Engineering	Tests of Cast Iron and Reinforced Concrete Culvert Pipe.
	Morgan Brooks	Electrical Engineering	Alternators in Parallel.
1909	A. Bement	Civil Engineering	The Illinois Coal Field.
	R. H. Rice	Electrical Engineering	Low Tension Feeder Systems for Street Railways.
	O. Chanute	Mechanical Engineering	Recent Progress in Aviation.
1910	C. K. Mohler	Civil Engineering	Earth Pressures.
	H. B. Gear	Electrical Engineering	Diversity Factor in the Distribution of Electric Light and Power.
	C. P. Berg	Mechanical Engineering	Heat Treatment of High Speed Tools.
1911	John Ericson	Civil Engineering	Investigations of Flow in Brick Lined Conduits.
	H. Gansslen	Mechanical Engineering	Ball Bearings for Heavy Loads.
	Chas. F. Burgess	Electrical Engineering	Electrolytic Corrosion of Iron in Concrete.

STENOGRAPHER'S REPORT OF REMARKS AT ANNUAL MEETING, 1913.

The Forty-third Annual Meeting and Dinner of the Western Society of Engineers was held at the Hotel Sherman, Chicago, Wednesday, January 8, 1913. After the dinner the meeting was called to order by President W. C. Armstrong.

President Armstrong: It is hard to be obliged to turn our attention to more serious matters after such an enjoyable feast, but we have other things to occupy our attention this evening.

The first will be the Secretary's Report for the past year.

The report of the Secretary was read and is printed elsewhere in the *Journal*.

Mr. W. C. Armstrong delivered his address as retiring President and introduced Mr. Albert Reichmann, the President-elect, who also delivered an address. Both addresses are printed elsewhere in the *Journal*.

President Reichmann: Gentlemen, I have the honor of presenting Judge Cutting to you, who will be our toastmaster. He needs no introduction. I am sure we have all heard of Judge Cutting.

Judge Charles S. Cutting: Mr. President and Gentlemen—I had almost said fellow professionals.

A Voice: It ought to be.

Judge Cutting: There was a time when a man would have hesitated longer about that than I did, because I can recall in my early school days when he who did not study in college for the degree of A. B. was considered an inconsequential sideshow to the institution. Now I notice from statistics and from my own experience that the men who are learning how to do specific things and are termed, in the parlance of this generation, engineers, outnumber all the other people pretty nearly, and that they are the ones who are the people.

You are becoming exceedingly popular, and if anybody wants to tunnel a mountain, to build a bridge across a navigable river, or level a lawn, he hires an engineer, and the engineer does each one of them apparently with equal facility.

I have always stood aghast at what I believed to be the knowledge of the engineer. He knows so much, and if you accuse him of it he admits it so readily that there is no wonder that all of us who are not on the inside stand constantly aghast.

I hear the stories of the tremendous studies in mathematics through which you have dragged your brains, that you know all about the inner workings of logarithms, that you have heard all about integral calculus, and that

you have dived into the higher mathematics,—excuse the expression, please—that you have *climbed* into the higher mathematics.

For a long time I was in doubt as to whether or not there was any direct relation between my own profession and yours. I am convinced beyond further doubt that there is. This came to me for two reasons. In the first place, I have listened to your testimony as expert witnesses. I have found that, with a unanimity which is appalling, the gentlemen who are called on the side of the plaintiff agree almost to a decimal as to the amount of excavation that would be necessary to complete the contract, and that with a unanimity which is equally appalling the engineers called on behalf of the defendant differ about 19,000 yards with those called on the other side.

This so reminds me of the same unanimity with which the gentlemen of the medical profession and the legal profession swear upon their respective sides, that I am ready to welcome you into the category of the professions.

You have another point of resemblance which is equally convincing. You are ready to stand by one another as to the value of your services. This is so exclusively and particularly legal that I almost call every one of you "brother."

I had long been in doubt as to the exact name by which you should be called until an incident occurred in my own court which settled that proposition forever. The precedent is controlling and final.

I was investigating one day something relating to the disappearance of funds which had been entrusted to an administratrix, and the husband of the aforesaid administratrix was upon the stand telling how he had obtained from his wife, who was the administratrix, these same funds and how he had spent them consistently in riotous living. The aforesaid husband was a man of exceedingly dark brunette countenance, born in Mississippi. He had, he said, an education and he was proud of it, and he did not wish anybody to think that he was an ordinary negro. He had in his pocket, among other things, a license as a stationary engineer. He tried to make the vault clerk of my court believe that he was entitled to take out files and receipt for them on the theory that a stationary engineer's license was equivalent to a license to practice law, but he failed in that particular. On the stand he was explaining to me that he and his wife had separated forever, and said they were persons of unlike tastes.

He also said, "You know, I am a graduate of a technical school in Mississippi. My wife scarcely reads and writes. In fact, Judge," said he, growing confidential, "she is domestic and I am a technicality."

Another connection between your profession and mine. We are accused of a characteristic liking for technicalities. We are not always guilty. But if you are technicalities, as your brother from Mississippi announced, we shall not love you any the less. We are accustomed to you and it does away with our awe of you, because we know how to handle technicalities.

But, gentlemen, I forget myself. I am the toastmaster. If I can get hold of the insignia of my office here, I will prove it to you. (Taking gavel.)

It is not my intention to make a speech, and I am not going to. You understand the duties of the toastmaster. If you do not, let me tell them to you in rhyme.

The toastmaster bold is a merry old soul,
As merry as soul can be,
For he talks and he talks and he talks again,
But never a thing says he.

He spins his yarns and he cracks his jokes,
The points of which no one can see,
And he talks in rhyme with a gall sublime,
But never a thing says he.

With an evergreen hope he spreads his soft soap,
As he trots out his speakers three,

And he giggles and guggles and wrestles and struggles,
But never a thing says he.

It is my duty, gentlemen, to demonstrate to you the truth of these classic lines.

I have the great pleasure, as well as honor, of introducing to you tonight a gentleman who has come to us from the University of Pennsylvania. I refer to Dr. Emory R. Johnson, who will speak to us on the subject of Panama Traffic and Tolls, and in these days whenever the common people, like myself, hear the name Panama and have brought to our consciousness what has been accomplished by the American engineers, we take off our hats in reverence.

Gentlemen, I present to you Dr. Johnson.

(Dr. Johnson's address is printed elsewhere in this issue.)

Judge Cutting: Gentlemen, I am sure we have all been greatly educated on this subject, which is sure to be a burning one in the immediate future, but our journey carries us from somewhat distant Panama to immediate Chicago. Such is the jurisdiction of this Society. We are going to have things better after a while, and we are going to have them like those concerning which I am about to tell you.

The story goes that not long since an Irish policeman, who was engaged in the performance of his arduous duties, walked into the station house and said to the sergeant, "Sergeant, there is a dead horse over on Kosciusko Street."

"O," said the sergeant, "sit down and make out your report."

He sat down. He wrote a few moments and commenced to bite the end of his pencil. He looked over his shoulder and said, "Sergeant!"

"Well, what is it?"

"How do you spell Kosciusko?"

The sergeant looked at him with a severe frown and said, "You are making out that report. I'm not."

Another period of mental turmoil and O'Brien took up his hat and started for the door.

The sergeant said, "Officer O'Brien, where are you going?"

He said, "I am going to haul that dead horse over into Halsted Street."

When the next speaker gets things his own way there won't be no Kosciusko Street, as the boy said about the apple core.

Chicago has been fortunate in many things. She has been fortunate many times in her citizenship, but she was never more fortunate in that behalf than she was when there was produced within her borders a man who, although perfectly able, so far as finances go, to live either in the East or in Europe, concluded that it was a portion of his duty to make the city which had given him birth and from which his fortune had been derived some benefit of his experience and his good will.

I say today every man of us is proud of the fact that we have Mr. Charles H. Wacker, who knows about the Chicago of the future.

I present to you, gentlemen, Mr. Charles H. Wacker.

Mr. Charles H. Wacker then delivered his address on The Chicago Plan (printed elsewhere in this Journal). It was illustrated by stereopticon views and received with prolonged applause and cheers.

Judge Cutting: Gentlemen, for this splendid exposition of the possibilities of our city, I am sure you will sanction what I said in the introduction of the last speaker.

I know that the experience of an Irish friend of mine will not be repeated when the next speaker addresses you. A friend of his, of the same persuasion, said to him:

"Mike, do you like lettuce?"

He said, "I don't and I am glad of it."

He asked, "Why are you glad of it?"

"Why," he said, "if I liked it I'd ate it and I hate the dommed stuff!"

I am sure you will like this and eat it and you won't hate it when you get through.

I have great pleasure in introducing to you Dr. Clarence B. Strouse, of Virginia, who will speak on anything he pleases.

Clarence B. Strouse, Ph. D.: Mr. Toastmaster and Gentlemen: I have been very much entertained and instructed while listening to the able addresses of the speakers who preceded me. My presence on this program is in a way quite a surprise to me, and the reason for it I am not able to make out. I did not know as to the nature of the company in which I was coming; however, I am not ashamed of it. But I want to say that I do not know that it has added anything to your prestige to be classed as brethren by one of the legal profession.

Judge Cutting: I only did it as a compliment; that is all.

Dr. Strouse: Although the hour is growing late, the introduction given me is more flattering, if not so appropriate as an introduction which I received not long since. I was attending a school entertainment in Virginia. A gentleman in charge of the affair arose and said, "Now that the entertainment is over we would like to hear a few words from Dr. Strouse."

I was wise enough not to choose any subject for this evening. In the first place, I did not understand the serious nature of the occasion, because over the telephone the secretary simply stated that it was a meeting of engineers—all varieties of engineers. Of course I have the orthodox idea as to that daring class of men who most deserve the title of engineers. Hence, I do not feel entirely out of touch with you, since I have already had the honor of addressing the Brotherhood of Locomotive Firemen.

Nevertheless I did not expect such a serious occasion. I have learned from our toastmaster of your great learning and remarkable ability. He has informed us that you know everything and that you accept the accusation without resentment. Hence, it is impossible for me to do the wise thing,—choose a subject that you do not know anything about. This leaves me in a dilemma and I am at a loss to know just how to proceed. I have one advantage, in that I can be very wise in not proceeding at all at this late hour—the entertainment being over. The secretary has exercised discernment in placing me at the end of the program—somewhat in the nature of a caboose. One thing about the caboose is that you can cut a train anywhere and put on the caboose and the train is complete. I realize that the caboose is not intended to carry any freight—it is simply dry and empty.

At this late hour the speaker should get a good deal of credit—I am simply making a suggestion—when from a humanitarian spirit he declines to persecute a body of patient working men, and especially when the presumption is that he has many brilliant things which he would like to say and which he would say if time sufficed; thus getting credit for the ability without having to make good. I shall take advantage of this rare opportunity.

My orthodox idea of engineers has always led me to divide them into four classes, and I should address myself to any representatives of the different classes that might be present this evening, if it did not entail a violation of that spirit of consideration for my audience which in kindness to them I am taking advantage of. However, I am sure you are familiar with the four classes of engineers to whom I would naturally address myself—viz: Locomotive, stationary, donkey and gas. Not being familiar with the records of your association I, of course, would not be able to classify your membership or to know the predominating class here represented. From your hearty response I conclude that my classification is significant as well as appropriate.

My talk to the firemen was quite an easy task, because they easily

understood an ordinary joke and the speaker was not liable to offend their dignity or be subjected to the scrutiny of technical measurement. The seriousness of this occasion has grown upon me each moment since I have been your guest. I have come to know that you are a serious body of men who take yourselves most seriously. I can readily understand why I am the only speaker of the evening who has had the presumption to appear before you without a carefully prepared manuscript, and I find myself in this position by mistake. I understand now that your banquets are important educational affairs, given for the expressed purpose of acquiring additional knowledge, which your devotion to your profession makes it impossible for you to acquire, were it not bestowed upon you while you ate. I am convinced that a large part of your education has been acquired at banquets.

I must confess that I see you as a body in an entirely different light from that in which I viewed you when I first arrived. The change that has taken place is remarkable. If I did not see several familiar faces I would be convinced that I was in the wrong company. The sudden change makes me feel somewhat like the chief mourner at a funeral which took place in the mountains of Virginia. A friend of mine who conducted the funeral said that he was never called upon to visit a certain mining camp in the mountains except on two occasions—to celebrate a wedding or to preach a funeral, and that he always found them under the influence of liquor, either from the wedding or the wake. He had a hurry call to officiate at a funeral; when he arrived they were all assembled, with every evidence of free indulgence in the comforting spirits. He took his place behind the pine box—with a window glass arranged in the top—made to suffice for the ordinary coffin. Before he had finished reading the service he happened to glance down at the glass and instead of seeing the face of the deceased he saw two brogan shoes—with the mud still on them—under the glass. Some gentleman a little under the weather had placed the top on wrong end to. My friend said the sight was so ridiculous that he could hardly restrain his desire to laugh. When finally he finished the service with the usual Amen, the chief mourner immediately arose and said, "Brethren and sisters, now come on and take a last view of our deceased friend," and he led the way. He came up to the glass and looked down, then he closed one eye and looked. Then after looking quite a while he pulled out his handkerchief and commenced to cry, and raising one hand, he said, "Go on back, brethren, go on back, there ain't no use in your coming. He's changed so fast you wouldn't know him."

Gentlemen, my ideas of you have undergone such a change that I would not really know you by the ideas I had before you were laid out. I will keep my promise and will not presume upon your kind attention any longer. However, I want to express my appreciation of your invitation. I come from a state which is famous for her cordial greeting and hospitality. I appreciate the opportunity to meet representative men that go to make up the real opinions and sentiment of this country. I have a great many things on my mind and heart that I might say which might further a better understanding of the Southern heart and mind. I am glad that the last remains of sectionalism which has lingered in politics is about swept away and that our nation is more thoroughly one than ever before in its history.

In closing I will offer as a toast a few lines which I have written in honor of my native state.

DEAR OLD VIRGINIA.

The mountains nowhere seem so grand,
Nowhere such flowers and fertile land,
Nowhere do sunbeams kiss the strand,
As in Virginia.

Friends nowhere are quite so true,
Their warm hearts blood is royal blue,
A hearty welcome awaits you,
In old Virginia.

Men revere sweet woman's name;
They die to shield her virtue's fame,
For lovers nowhere love the same,
As in Virginia.

If you haven't seen earth's paradise,
It is because your luckless eyes
Have ne'er beheld a clear sunrise
O'er old Virginia.

And when I meet death's fatal rod
Please take me back to that dear sod,
That I may rise to meet my God,
In old Virginia.

For boasting of his native land,
Won't you forgive a homesick man,
Because he loves each grain of sand
In old Virginia!

I thank you.

Judge Cutting: Gentlemen, I have been waiting all the evening to congratulate you, but the feature I expected is absent. When I heard your Secretary's report I was sure that somebody would move to declare a dividend, but the evening has gone and this had not been done.

I return the gavel to its lawful owner and bid you good-night.

LIBRARY NOTES

The Library Committee desire to return their thanks for donations to the Library. Since the last publication of the list of such gifts, the following publications have been received:

MISCELLANEOUS GIFTS.

H. G. Tyrrell, M. W. S. E.:

Transporter Bridges, H. G. Tyrrell. Pam.

E. E. R. Tratman, M. W. S. E.:

Journal of Railway Signal Association, December, 1912. Pam. University of Arizona Agricultural Experiment Station Bulletins Nos. 60, 64. 2 pams.

Louisiana Board of State Engineers. Report, 1910-12. Pam.

Locomotive Drafting and Its Relation to Fuel Economy, H. B. MacFarland. Pam.

Some Facts About Treating Railroad Ties, W. F. Goltra. Pam.

Report of Tests of Partitions by Fire and Water, Cleveland, O. Pam.

Administration Report of the Railways of India for year 1911. Folio.

Prof. W. E. Lilly, Dublin, Ireland:

The Design of Plate Girders and Columns, Lilly. Cloth.

The Strength of Columns, Lilly. Pam.

A New Formula for the Design of Arches, Lilly. Pam.

The Elastic Limits and Strength of Materials, Lilly. Pam.

A New Torsion Testing Machine, Lilly. Pam.

D. Van Nostrand Co.:

Water, Its Purification and Use in the Industries, W. W. Christie. Cloth.

EXCHANGES.

Wisconsin Geological and Natural History Survey:

Sandstones of the Wisconsin Coast of Lake Superior. Cloth.

American Society of Civil Engineers:

Transactions, 1912. Pam.

Lake Superior Mining Institute:

Proceedings, 1912. Pam.

Michigan Board of Health:

Annual Report, 1911. Cloth.

Massachusetts Board of Health:

43rd Annual Report. Cloth.

Los Angeles Board of Public Utilities:

Second and Third Annual Reports, July 1, 1910, to June 30, 1912. Pam.

Engineering Association of New South Wales:

Proceedings, 1910-11. Cloth.

Wisconsin Railroad Commission:

Various Reports and Decisions. Pams.

Philadelphia Bureau of Surveys:

Annual Report, 1911. Cloth.

Southwestern Electrical & Gas Association:

Proceedings Seventh Annual Convention, 1911. Cloth.

Boston Transit Commission:

18th Annual Report, June 30, 1912.

Boston Public Works Department:

Annual Report, 1911. Cloth.

American Society of Heating and Ventilating Engineers:

Proceedings, 1911. Cloth.

Universal Portland Cement Co.:

Monthly Bulletin Universal Portland Cement Co., 1912. Leather.

MEMBERSHIP

Additions.

Balzer, Fritz, Chicago, Transfer from Associate Member to	Member
Bennitt, Ralph A., Champaign, Ill.....	Student Member
Brown, John F., Chicago.....	Member
Burton, Earl K., St. Louis, Mo.....	Junior Member
Dye, Ira W., Culebra, C. Z.....	Associate Member
Fuller, Clarence M., Champaign, Ill.....	Student Member
Griffith, C. P., Champaign, Ill.....	Student Member
Hendricks, S. P., Salt Lake City, Transfer from Junior to	Associate Member
Huffman, Frank C., Pekin, Ill.....	Member
Irving, Thomas J., Springfield, Ill.....	Member
Lockard, Bernard M., Mason City, Ill.....	Associate Member
Loeffler, Frank X., Champaign, Ill.....	Student Member
Misostow, Henry, Chicago.....	Associate Member
Stineman, N. M., Chicago, Transfer from Junior to.....	Associate Member
Turley, Everett W., Chicago.....	Junior Member

Changes of Address.

Budd, Ralph, care of G. N. Ry. Co., St. Paul, Minn.
 Dance, M. H., Holmesville, Miss.
 Frost, W. G., Healdsburg, Cal.
 Main, W. T., Silverton, Ore.
 Rockwell, J. V., Navy Dept., Washington, D. C.
 Sargent, C. E., 2226 N. Meridian St., Indianapolis, Ind.
 Spielman, J. G., 1312 W. Eleventh St., Los Angeles, Cal.
 Symons, W. E., Supt. M. P., S. A. & A. P. Ry., San Antonio, Texas.
 Weston, C. V., 1606 Harris Trust Bldg., Chicago.

Deaths.

Johnson, James W., Chicago, January 14, 1913.

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THE NATIONAL ASPECT OF THE RECLAMATION OF SWAMP AND OVERFLOWED LANDS

EDMUND T. PERKINS, M. W. S. E.

Presented November 18, 1912,

Three political parties, in their platforms of 1912, recognized the national aspects of the regulation and control of the flood waters of the Mississippi River. These three parties polled more than fourteen million votes at the presidential election.

The plank in the Republican platform reads: "The states unaided cannot cope with this giant problem; hence we believe the federal government should assume a fair proportion of its control, so as to prevent the disasters from recurring floods."

The Progressive platform reads: "It is a national obligation to develop our rivers, and especially the Mississippi and its tributaries, without delay, under a comprehensive general plan covering each river system from its source to its mouth—designed to secure its highest usefulness for navigation, irrigation, domestic supply, water power, and the prevention of floods. We pledge our party to the immediate preparation of such a plan, which should be made and carried out in close and friendly co-operation between the nation, the states, and the cities affected."

The plank of the Democratic party, which was successful at the polls, reads: "We hold that the control of the Mississippi River is a national problem; the preservation of the depth of its waters for the purpose of navigation, the building of levees to maintain the integrity of its channel, and the prevention of the overflow of the land and its consequent devastation, impose an obligation which alone can be discharged by the general government. We favor the co-operation of the United States and the respective states in plans for the comprehensive treatment of all waterways."

Thus the largest three political parties have officially declared the regulation and control of the Mississippi and its tributaries to be a national problem. This official declaration has been upheld and supported by the approving votes of fourteen million voters. So far as it might ever have been a political question, it is disposed of; and it would seem that the verdict is so over-

whelmingly in favor of having federal government discipline its unruly rivers, that the question need never become a partisan issue. It never has been an economic issue; there never has been a time when anyone would question the statement that floods should be prevented and their attendant loss of lives and property done away with. From this point of view it always has been a question of expedience, a question as to whether the cost would not exceed the gain, or a question as to whether it would be possible to do the work. The question of possibility has been disposed of. Engineering and construction achievements in all parts of the world in the last few years have shown, by inference, that the engineering skill and the constructive skill necessary to control and regulate the Mississippi and tributaries can be had.

The Mississippi River is 2,446 miles long (Annual Report, Chief of Engineers, U. S. A., 1909, page 2677), and has a drainage area of 1,242,650 square miles (Bulletin No. 38, Weather Bureau, No. 435 Department of Agriculture, page 5). This is equal to two-fifths of the total area of the United States. The headwaters of its tributaries extend from New York on the east to northern Montana on the northwest and into Canada on the north.

Yet, great as is the national problem of controlling and regulating the Mississippi, it is only a part of the problem of our swamp and overflowed land of approximately 74,000,000 acres lying in almost every state in the Union. The vast benefits to be derived from the reclamation of this great area are too obvious to require comment. It is generally known that these acres possess wonderfully fertile soil, capable of producing great crops for many years without defertilization to any marked degree.

The U. S. Department of Agriculture touched on this subject in Circular No. 76, Office of Experiment Stations, on "Swamp and Overflowed Lands in the United States," issued in 1907. The circular (basing the acreage to be reclaimed at 77,000,000) states:

"In those states where large areas of swamp land have been thoroughly drained by open ditches and tile drains, the cost ranges from \$6.00 to \$20.00 per acre, while in places where tile drainage was not required the average cost has not exceeded \$4.00 per acre. Judging from the prices which prevail in a large number of these districts where work of this kind is being carried on, it is safe to estimate that the 77,000,000 acres of swamp can be thoroughly drained and made fit for cultivation at an average cost of \$15.00 per acre. The market value of these lands in their present shape ranges from \$2.00 to \$20.00 per acre . . . with an average of probably \$8.00 per acre. Similar

lands in different sections of the country that have been drained sell readily at \$60.00 to \$100.00 per acre at the completion of the work, and in many instances, when situated near large cities, they have sold as high as \$400.00 per acre. To determine whether or not it will pay to drain these lands, we have but to consider the following figures:

Cash value of 77,000,000 acres after thorough drainage, at \$60.00 per acre.....	\$4,620,000,000
Present value of this land at \$8.00 per acre	\$ 616,000,000
Cost of drainage at \$15.00 per acre	1,155,000,000
Value of land and cost of draining	1,771,000,000
NET INCREASE IN VALUE	\$2,849,000,000

"These figures," the report continues, "though large, are not fanciful but are based on results obtained in actual practice in different sections of the country where work of this kind has been done."

Since this circular was issued by the Department of Agriculture in 1907 many swamp and overflow acres have been reclaimed; the cost of reclamation undoubtedly has risen with the general increase in cost of things, but the value of the land also has risen, so it may be conservatively supposed that the net result as figured in 1907 is approximately the proper figure for today, upon the assumption that 100% of these lands could be reclaimed, which of course we know to be impossible.

Now, the reclamation of the great bulk of these swamp and overflowed acres is largely dependent upon the control and regulation of the Mississippi and its tributaries.

From the headwaters of this great river system to its mouth, as in every other stream, it is not possible to reclaim or correct one part without at the same time exerting some influence, either for good or bad, upon the other portions. It is the same wherever we go. There is only one drainage problem in the valley of the Red River of the North, where the swamp lands are partly in Minnesota and North Dakota; one problem in the Okefinokee swamps of Georgia, which must be drained across Florida; one problem in the drainage of the Great Dismal Swamp of Virginia and North Carolina; one problem in the Sacramento Valley of California.

This is a natural fact. When we try to subdivide one of the problems and solve each subdivision from our own limited viewpoint, and for our personal, selfish interests, we are making

trouble for ourselves or someone else, or both. We are doing more; we are violating the laws of nature which, before the arrival of man, established these drainage basins and provided these drainage problems for us to solve. There is only one right solution to every problem; there may be found ways to find many answers, but only one of these can possibly be the best.

Can we establish arbitrary boundaries, often in ignorance of existing physical conditions, ignoring natural problems and necessities, and say: "Here, this political body shall have jurisdiction, and there, that one?"

No set of resolutions or legislative enactments can change the physical characteristics and drainage necessities of such an area as the St. Francis basin, which man has decreed shall be partly in Missouri and partly in Arkansas. Yet the Missourians are "showing" the Arkansans and draining their part of this basin, sending the surplus waters into Arkansas to the detriment of that state.

How can the matter be adjusted under two interested jurisdictions? You may say that common purpose and mutual agreement will succeed. Where is your shining example? A third party, unprejudiced and uninterested, must arbitrate to obtain a logical and successful result, and between the sovereign states there can be but one common authority—which is the federal government.

A Southerner myself, I believe in the sovereignty of the state and the preservation of state rights, but not to an extent where logic and common sense show the fundamental creations of God in opposition to the red tape of human legislation.

Here is a problem that has been present with us since our country was settled, but one that has continually been passed by. No longer should this be done; no longer can it be done. First of all, because it is a national question of health. Even if we are sluggards and would rather travel far off on seeming easy roads to wealth than to wrest the rewards of honest labor from our own lands, these same lands in their present condition are the greatest single existing menace to our public health.

Yellow fever seems to have gone, but it may come back; malaria is ever with us, a deadly blight to all human effort and life; no longer is it a question but that the mosquito, bred in these swamp lands and low, wet places, is the agent that perpetuates and disseminates these fevers. The national government has spent money in huge sums to fight these plagues. Is it not wiser far, and constitutional as well, to spend money to prevent as well as to fight?

Mr. M. O. Leighton, of the U. S. Geological Survey, suggests that if there lay, off our coast, a wonderful, fertile country, 75,000,000 acres in extent, peopled by a race, vicious, blood-

thirsty, marauding, and death-dealing, every year invading our coast and killing and carrying away thousands of our people, and always promising to come back for more victims, we would soon see a unanimous uprising of our people. All the money in our treasuries, national and state, would be made available and the aforesaid marauders would be wiped off the face of the earth and their country annexed. But because these same lands are our own, under our flag, we do not inhabit them; on account of political subdivisions we let them lie idle and allow the hideous enemy—disease—to remain there to again and again attack us.

Patriotic, sentimental, and sanitary arguments are not needed to justify the reclamation of these swamp acres. A body of land as large as Ohio, Indiana, and Illinois, is unreclaimed and unfarmed, while there is a constant demand and search for more farming land. Until recent years there was a surplus of good agricultural land in the West that could be homesteaded at slight cost. The railroads and the lands agents advertised these acres throughout the world until those most easily reclaimed were taken up. There went up still the cry for land, and the sectional issue of irrigation was made a national issue and the splendid Reclamation Act became a law. The operation of that act has brought hundreds of thousands of acres under cultivation and made many happy homes. This has been done without any adequate means of making known to the people of the country the opportunities that existed, for our government, in all departments, has no advertising fund and many thousands of dollars go into most valuable investigations and experimental work which does not reach the people, for lack of money to convey the information to them.

The reclamation of the arid lands by irrigation did not supply the demand for more land, and as good farm lands became scarcer and values increased our farmers went further afield, notably to Canada. The Canadian government, realizing the great value of American farmers for citizens, has conducted and still conducts a regular colonization campaign. Hundreds of thousands of our land-hungry men have gone across the border, always shirking the reclamation of the lands that lay at their door. The end of the rainbow is a long way off.

Some men are chronic wanderers; they were born that way. There always will be many who will expect to find the end of the rainbow in some distant place. There always will be many who will be unable to see that the bow ends at their feet and the pot of gold is within their reach. But there will always be others endowed with a quality of imagination that approaches a degree of prophecy, who can look beyond today or tomorrow or next year, and see what must be done, what can be done, and what will be done; men who can look through the mist and the slime of the swamps and see fertile farms, happy homes, and prosperous cities

where today there is only waste—economic waste, industrial waste, health waste.

I have known the Illinois man going to Louisiana; the Louisianan to Texas; the Texan to California; the Californian to Canada; the Canadian to Illinois. The peasant of Europe who dreams vaguely of a time at some far-distant day when he may own the little patch of ground which he cultivates so laboriously and so patiently, is not more land-hungry than the average American, native born, foreign born, rural or urban dweller. We call it land-lust, but it is something far deeper. It is a longing, a hunger, based upon the fundamental nature of human life. Whether we are all conscious of the fact, or not, still we know that upon the soil depends human life. The ancients recognized this great underlying human essential in the story of Antaeus whose strength returned every time his feet touched the earth, and who was finally conquered by Hercules only when the giant discovered that secret and held his opponent in the air until his strength was exhausted.

So it is a natural, normal thing for us to want land and to hunt for it. But it is not necessary for us to shut our eyes to the great possibilities close at hand and go chasing the rainbow far afield. There are fertile farms for a million families under the swamp and overflow waters,—perhaps for many more than a million families, since the soil is so rich that a small acreage is amply sufficient.

Our rural population is not keeping pace with our city population; in some localities the rural population is actually decreasing in numbers as well as in percentage in comparison with the urban population. The number of our farms has increased only slightly in the last ten years.

There has been a steady increase in the cost of food consumption,—an increase more rapid than the gain in food production,—and the high cost of living is the bogey man that's going to catch us if we don't watch out.

If Uncle Sam does not want to keep his good farmers, Canada will be glad to welcome them—is welcoming them. Through the middle west there are nearly a million tenant farmers,—good farmers, good workers, intelligent and ambitious. A few of them can save enough money to purchase the high-priced lands in their own neighborhood; the great majority cannot. But Canada has an eye on these men; Canada wants them; wants them to go over the border and become land owners and Canadian citizens. In fact, so eager is Canada to secure these men to own and cultivate its land, that one of the principal Canadian railroad companies has set aside a great fund for the purpose of loaning money to American tenant farmers who want to go into western Canada and buy cheap Canadian lands. The conditions this company makes are that the man shall be married, have a

family, and have enough money to transport himself and his personal property to the place where he wants to settle. Then the company will sell him the land at a low price and give him ten years in which to pay for it, or let the crops pay for it out of the net profits. In addition, the company will loan the settler from \$2,000 to \$2,500 to improve his farm, and give him ten years to repay the loan.

But why should we let our good farmers be enticed into Canada or any other land? Not because of lack of land in the United States certainly. There is no such lack. There are millions—hundreds of millions—of acres of good land in the United States unoccupied, uncultivated. There are more than 2,000,000 acres in the state of Illinois that are lying idle, that could be made to yield abundant crops. Less than half the land area of the United States is included in the farm area, and of that which is included in the farms little more than one-half is cultivated. Our people are not going to Canada because the United States is over-populated. It has been estimated that the state of Illinois can furnish food to support a population of 20,000,000. The population is less than 6,000,000. There are vast areas of good farm land in Texas, unoccupied; vast areas in many other states. Even in Rhode Island and the rest of New England, and in New York, and other eastern states, are large areas of unproductive lands that can be made to yield abundantly.

I have been wandering over the United States for twenty-seven years, inspecting and surveying lands. I am thoroughly convinced that there is no lack of land and of good land. With a total land area of approximately two billion acres, we are farming only approximately half a billion.

Yes, there is plenty of land; there is plenty of wonderfully fertile land if we will only use our common sense—which is our engineering sense—and reclaim what we have. And the land for each one to reclaim is the land that lies in his back door yard.

That is a matter of detail—and not the general plan. Physical, economic, social reasons demand that the reclamation of these 75,000,000 acres of swamp and overflowed lands, and the control of the waters that cause them, must be undertaken in a broad and comprehensive way—in a national way—and this cannot be done offhand.

There is no cure-all, no panacea. Careful investigation and study must be had that there may be developed a plan founded upon justice, equity, and good engineering. It must be constitutional, not only as regards the nation but as regards each state affected. In addition, every beneficiary, nation, state, corporation, individual, must in due proportion bear the expense of the improvement producing that benefit, either direct or indirect. With the insufficient data available I would hesitate to accept or reject at this time any particular plan.

There is no part of this great problem that has been given more study to date than the Mississippi River, and how unsatisfactory are the results! We have no absolute knowledge of the inter-relation of the various parts of this river. All of our conclusions are based on incomplete data. The consequence is that good men disagree, according to their point of view and their interests, as did the two knights of old who, approaching the shield from opposite sides, fought over the question as to whether it was gold or silver; dying, they saw that each was right, for the two sides were of different metal, and as they fought they had changed their positions until, too late, each had attained the other's viewpoint.

In discussing flood control of the Mississippi there are some who argue for levees and levees only; and some, I have been told (though I have not personally met this *rara avis*) argue that since levees so far have failed to give everlasting, eternal, and complete protection, they should be abandoned and the country cultivated only in times of low water, while the high places are still further raised to furnish points of refuge for men and beasts when the floods come. We might as well abandon our railroads when an accident occurs.

There are some who say "double-tracking" the Mississippi will save the day; that is, provide new and additional channels from various points to the sea. This is an unproven remedy and a problem that should be approached with caution.

The people of Pittsburgh had a flood in 1907 causing damage amounting to about \$10,000,000. They "got busy," raised a sum of money sufficient for surveys and report, and now gleefully announce that they have the answer. They say that by the construction of dams and the establishment of reservoirs at seventeen selected sites, for an expenditure of \$20,000,000 they can take ten feet off the crest of the flood and reduce it below the danger line.

The question of reservoir construction as a means of flood control and river regulation was touched upon by Colonel Townsend, Corps of Engineers, U. S. A., and President of the Mississippi River Commission, in an address before the Interstate Levee Association at Memphis, Tennessee, September 26, 1912.

"On the Upper Mississippi," said Colonel Townsend, "the Corps of Engineers has constructed the largest system of reservoirs for regulating rivers that has been built in any country, having nearly twice the capacity of those proposed by the Pittsburgh Flood Commission for controlling floods at Pittsburgh. These reservoirs have been most successful, not only for increasing the low water discharge of the Mississippi River above St. Paul, the purpose for which they were constructed, but also for reducing floods in that portion of the river." These two facts mightily cheer the advocates of protection by construction of reservoirs.

Personally I insist that the only way we can get an answer to the question is by a systematic survey and study of the entire drainage basin of the Mississippi and its tributaries. That will require many years and it will cost hundreds of millions of dollars to carry to a successful completion the plan that may finally be adopted. A beginning is necessary, however, and we must proceed upon the theory that "every little helps" while holding steadfastly to the goal of thorough and complete regulation and control of the waters, and the reclamation of the lands and their utilization for the good of the entire people.

Reforestation in some sections will retard the runoff and prevent erosion with the consequent silting up lower down the stream. Reservoirs will furnish hydro-electric power, decrease high water discharge, increase low water discharge within certain distances dependable upon varying factors and have a marked influence upon the regime of the river. On the lower reaches there may be by-passes that will partially relieve the main channel when most necessary.

Then there must be levees and bank protection everywhere. On this we can probably all agree. A number of years ago the Mississippi River Commission established a provisional grade line to which the levees should be built. Though this was fifteen years ago, they have not had funds to carry out their recommendations. Had this been done, said Col. Townsend, the disaster of last spring could have been almost entirely prevented. That is, there would, at all places, have been a fighting chance, a good fighting chance.

So, while we are at work on the general, comprehensive plan for river regulation and flood control, let us in every way aid the immediate need of procuring sufficient funds for the Mississippi River Commission to bring their levees to this provisional grade, and bring them to this grade with standard dimensions. This work will cost enough millions to astound us.

That work is necessary. It also is necessary to so provide that the future will not make this expenditure unprofitable, as, for instance, through caving banks and consequent loss of levees, which Col. Townsend says even now is costing nearly \$1,000,000 annually to replace.

But how shall we put into effect this general plan after we shall have formulated it?

The several states were granted all swamp and overflowed lands remaining unsold within their borders after September 28, 1850, for the specific purpose that the proceeds of their sale should be used in reclaiming them. So far as I know, Florida is the only state that is complying with the provision of the act, and except in Florida, practically all of these swamp lands have passed into private ownership in lots ranging from a few acres to many thousands, with the owners scattered about the world.

This condition of ownership is one of the difficulties that must be contended with. The Reclamation Act was designed to reclaim the federal lands of the West, and when private holdings were taken into a project it was by mutual consent and on a partnership basis. The government brings the water to the land after a certain percentage of the land owners in the project have agreed to join in its reclamation. No one is compelled to accept the use and benefit of this water if he has not so agreed, nor is he apt to be benefited individually unless he does pay.

In the case of swamp and overflowed lands, however, it is not practical to drain or levee part of the land without affecting the rest; each tract of land will be benefited whether the owner desires such benefit or not, or whether he wants to pay his share of the cost of reclamation. For this reason most of the states containing swamp and overflowed lands have passed drainage laws allowing certain majorities either of lands or owners, to form drainage districts and so compel all persons owning lands within the district that may be benefited, to help pay the costs of reclamation.

Just as the states can help the individual land owners to organize their drainage districts, so can the federal government, in planning a complete system covering the entire drainage basin, by means of complete surveys and plans, work out efficient and harmonious plans for each individual project, if desired, and have each individual project harmonize with the general plan covering the entire drainage basin. This, I hold, is a national duty and a national necessity.

DISCUSSION.

Lyman E. Cooley, M. W. S. E.: Mr. Perkins' discussion is very comprehensive and I think everybody agrees with him.

I have given a good deal of attention to the subject of reclamation in relation to other subjects of conservation. We have done a great deal of reclamation work in the country, but we have now reached those larger problems which must be approached in a larger way. I recall in my readings that when George Rogers Clark crossed the state of Illinois on his expedition from Vincennes to Cahokia he waded in marshes two-thirds of the way. That, of course, was a century ago. The history of the state of Illinois—the central part of the state—has been that the majority of the lands have been reclaimed, and are now part of its fertile corn belt. We have still in the state of Illinois something like 5,000 square miles of land—over 3,000,000 acres—subject to overflow in our great valleys, not including the swamp area in the uplands which are largely drained. That is an area larger than the state of Connecticut, larger than Porto Rico, and is certainly worth considering. Illinois is a state of valleys. It has valleys on three sides of it. I have considered the question of reclamation of swamp and overflow lands far more important

than the irrigation problems. It is estimated, I believe, that sufficient water is to be had on about 1,300,000 square miles in the United States to reclaim about 75,000 square miles, or about 50,000,000 acres. We have heard the statement here this evening that there are 77,000,000 acres of swamp lands in the United States. There are more than 50,000,000 acres in bottom lands along our great rivers. They are more advantageously situated for transportation than are those arid lands which are being treated by means of reservoirs and storage in the semi-arid region; they lie at lower altitudes; they lie along the water courses, along the main railroad lines which largely follow the valleys, where they have low grades for cheap transportation; they lie nearer to our great cities; they have a greater variety of production. Eighty to ninety per cent of the population of the United States in cities, is along the water courses. So these lands are not only capable of a greater variety of production, but are most favorably situated to attain great value and minister to the dense populations of the country. We have, between Chicago and the Gulf of Mexico alone, something like 25,000,000 acres of these swamp and overflow lands.

The author has called our attention to the fact that there are great difficulties to be encountered. What is the function of the national government, what are the functions of the states, and how far must we rely upon the localities themselves and the people directly interested?

The author has very properly called attention to the fact that the United States has no proprietary interest, such as it has in the lands of the semi-arid region, and it can only assist and reach the problem through its broad interest in conservation, through its interest in navigation, where its jurisdiction is paramount.

The question of what the states can do is a matter of some vexation on account of conflicting jurisdictions, to which the author has called attention. There is one feature in our constitution, however, which has not been invoked, I think, in any of these questions. Two or more states can coöperate, with the consent of Congress. With great interior problems it is feasible for a number of states to combine and work out their common destiny in such matters in a perfectly legal and proper procedure. This is one of the recourses which has developed in my mind in connection with our deep waterway problem.

I have come to look upon the matter, however, in the broader relation of conservation. It seems to me that the water courses must be treated as a whole and in all their parts in order to develop all their adaptations. The waters of the country are next in value to the land, and there is not only this question of lands to be reclaimed, but also the question of health, about which too much cannot be said. Malaria, perhaps, is the greatest economic

handicap in this country. It has blighted entire regions and even whole states, deferred progress and development, and this condition is to be largely remedied by reclamation of these overflow lands.

Again, the waters running to waste in this country, if properly utilized, can generate more power than all the coal which is now mined.

Then there is the question of navigation itself. In some basins it is feasible, by storage work, to multiply the low water flow from three to five times. If such policy is carried out over the country at large, in all the tributaries, it will profoundly affect the flow of main streams and bring the floods within practicable limits of control. It will so distribute the flow of streams as to make them navigable at all seasons of the year. It will produce water power, even to the remote head waters of source streams.

The values thus produced are only less than those of the land itself. All these interests are so related that we cannot treat one, and should not treat one, except as part of a comprehensive whole. The questions of the storage of water, of reclamation, of waterways, of water powers, and of public health in our valleys, are all parts of one related problem, and I am hoping that we may take the larger view and that we may find a way by which the states and localities and the United States may all coöperate to a common end. There are certainly sufficient lands in the United States, if they are properly developed and utilized, not only for our generation, but for the needs of the next hundred years.

A. Bement, M. W. S. E.: I think this is a subject that is generally not as well understood as it might be. I speak from the standpoint of an investor and the opportunity to make money. It seems that the farmer is the only one who grasps the situation; who discovers that a certain piece of land can be reclaimed by having the water taken off, and its value increased. It seems that it is only those men who are now in the agricultural, or some allied business, that appreciate the opportunities to make money in this business.

Mr. Perkins: Mr. Bement's statement is so thoroughly in accord with the facts that I want to give an instance which I think may be of interest. That is what I meant when I said that every man ought to reclaim the land that lies in his own back yard. Now, there are, as Mr. Cooley says, millions of acres in this state that can be reclaimed, and when reclaimed there are no better lands in the country.

On the Illinois River there are four pieces of land lying close together. Three of these,—approximately 6,000 or 7,000 acres each,—were reclaimed. They cost, unreclaimed, an average of \$15.00 or \$20.00 per acre. The cost amounted to \$30.00 per acre

to reclaim them, and that \$30.00 per acre was derived from bonds payable in fifteen or twenty years. Ninety per cent of the three tracts reclaimed was placed under cultivation; about 6% or 7% was used for roads, levees, ditches, etc., and about 2% or 3% for timber land. Those lands are yielding 12% and 14% annually on a valuation of \$150.00 per acre. The owners of the fourth tract of 7,000 acres have been trying for years to induce city capitalists to purchase a part of it, and help them reclaim all of it, but without success. Last week, however, some of the *neighboring farmers* put up the money to do it. The capitalists do not seem to recognize the fact that these lands can be reclaimed and become valuable, but the farmers do.

S. T. Smetters, M. W. S. E.: In an interstate river, or a river between two states, if a levee is built in one state to protect the land in that state, what right has the other state to charge damages on the land that would overflow because of the lack of a levee on the other side of the river? I know of a case where a levee was built on one side of a river, and it was proven that it raised the height of the water something like four feet over the maximum high water they had before on account of this levee. Suit was brought against the company, and I understand the Supreme Court of one state is going to hold damages against the people in the other state.

Mr. Perkins: My understandnig is that water is a common enemy, and all have a right to protect themselves against it; that is one of the facts of the law. You can protect yourself against it, and your neighbor has to protect himself, too, unless you subject him to some danger that has not previously existed.

Mr. Armstrong: The building of a levee on one side of a stream would probably change its course, and might throw it into a different channel, might make some old channel become the main channel of the river, and thus change the conditions. I understand no firm or corporation has a right to change the natural course of a stream of water. In a case of that kind, would not the parties injured have a right to damages?

Mr. Perkins: Yes, I think they would. There is a case now in Missouri where two districts are close together. One district is putting up a levee to protect itself against the waters that have been coming on it, and the attorneys say that no damages will lie against that district for protecting itself; but the district above is changing the course of the stream, and in that case the attorneys say the people who suffer loss will be able to obtain damages. Possibly that is the solution of the problem.

William Artingstall, M. W. S. E.: The author's remarks about the control of the Mississippi River brought to mind the very able paper presented before this Society by Mr. James A. Seddon, published in the JOURNAL, Vol. V, No. 4, August, 1900.

Mr. Warder: Mr. Seddon's argument was to use the St.

Francis basin as a reservoir to hold the surplus waters of the Mississippi River, and then release them from time to time, as may be necessary, to keep up the gauge of the river below.

Josiah Gibson, M. W. S. E.: I would ask if the building of reservoirs increases the swamp area in their vicinity?

Mr. Perkins: Of course, the building of a reservoir will cover a certain amount of land behind the reservoir, but there is hardly any case where the land that is included in the reservoir is not much less in area than the land which was flooded by the waters below the stream at other times.

To my mind, and as Mr. Cooley says, the river must be treated from its mouth to its source as one problem. We must help reclaim that river by doing what we can wherever we can. It is the same way with a great railroad system which pours its tremendous tonnage into Chicago; all of that tonnage does not come from any one place. It is picked up from other large cities, and from the smaller towns and villages. The villages pick it up from the farmers. In connection with the river we need to make corrections on the smaller branches and the larger branches, and all through. We need to save water in the reservoirs, to keep up the high water and keep down the low water, and keep the flow to use the stream for hydro-electric purposes. So, to handle the problem successfully, the river must be treated from one end to the other.

Mr. Armstrong: I think we all realize that this is a very interesting subject, one that in future years will become of more and more interest, one which I think will, in time, be considered not only by the states but by the federal government, and one on which engineers in particular will wish to be informed.

THE NORTHWEST STATION OF THE COMMON-WEALTH EDISON COMPANY

W. L. ABBOTT, M. W. S. E.

Presented at a Joint Meeting of the Electrical Section W. S. E., and the Chicago Section A. I. E. E., December 23, 1912.

In the days of direct current generating and distributing from central stations, when the fixed charges on the underground network were relatively greater than now, and the cost of underground copper was proportional to the square of the distance to which current was transmitted, a location as near as possible to the center of gravity of the load was the prime consideration in selecting a power house site. Naturally, in such cases land values were so high that it was found expedient to crowd the equipment into the smallest space possible, resulting in a congested station with high operating labor cost, running non-condensing and supplied with coal by wagon. With the development of A. C. generation and transmission at higher voltages, the use of rotary converters and frequency changers, and with enormous increases in the size of generating units and in the amount of power supplied, other operating costs decreased relatively to such an extent that the cost of fuel far exceeded them all combined. Therefore, the dominant factors now in determining the selection of a power site are the ones involving the economical handling and utilization of coal. Let us consider these factors and their effect on the problem:

As the cost of fuel greatly exceeds all other operating costs combined, and as the consumption of fuel when running condensing and non-condensing, respectively, is in the ratio of 2 to 3, it appears that unless the coal consumption is to be increased 50%, the power house must be accessible to an abundant supply of condensing water. This, then, is the first specification for a power house location.

If we assume \$1.70 per ton, f. o. b. cars, as the average price of coal in Chicago, and if we further assume that 60c per ton would be the minimum cost of cartage from a railway team track to the power house, it appears that unless the cost of fuel is to be increased 25%, the power house must be located adjacent to a railroad and preferably on the road which brings the coal to the city. Therefore, the determining factor of second importance is railroad facilities.

Desirable power house sites are hard to find, so when a satisfactory location is found it is advisable to provide for a good sized installation, and one which will take care of all increases in the load for a considerable period of time—say five years.

At the time the Northwest Station was to have been started (winter of 1911-12) the maximum load on the company's system was about 200,000 kw., and the indications were that for a number of years in the future the increase would average at the rate of

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15% per year, which rate of increase applied to the load of 200,000 kw. indicated that the net increase of load during the following five-year period would amount to about 220,000 kw. Accordingly, acreage sufficient to accommodate two power houses of 120,000 kw. each was sought. It was not the intention to install this amount of power all at one time, nor even during the five years mentioned, as our existing power houses could still be added to and other new power houses might be commenced, but it was considered that a site which might be built up at will and eventually accommodate 240,000 kw. would not be at all too large.

What acreage then is required to accommodate a 240,000 kw. power house?

Experience has shown that such a power house supplying a diversified metropolitan load will at some seasons of the year run at a load factor of 50% of the installed capacity. For a 240,000-kw. installation this will require a daily coal supply of something over 4,000 tons, or about 100 carloads. To make a moderate allowance for the uncertainties of freight traffic over a distance of 200 miles, provision should be made for storing on the property at least three days' supply of loaded and one day's output of empty cars, amounting altogether to 400 cars, which will require four miles of storage tracks.

Thanks to the effective team work of coal operators and coal miners, this market is subject to an interruption of its coal supply every two years, pending a discussion of the wage scale for the ensuing biennium, such interruptions lasting sometimes as long as three months. Therefore, to fulfill its obligation to the public and to properly protect its customers, a Public Service company of our kind should have facilities and room to store at least ninety days' supply of coal, which for the power house under consideration would be about 350,000 tons.

The power house, storage tracks, storage pile, and switch tracks will require about 50 acres of ground, but after allowing for convenient spacing, parking, and recreation grounds it will be found that the total space required for such a plant and all that goes with it is not less than 75 acres, the greater part of which is for receiving, storing, and handling coal.

Ample acreage we will call the third important factor in determining the location of our power station.

There remains for consideration a factor which I rank fourth, but which in the earlier days of the business, with smaller stations and with low tension transmission, was the first consideration, and that is nearness to load.

Let us now refer to the map of the city and see where we can nearest meet all of the various requirements which the nature of the problem has imposed upon us, which are a supply of condensing water, rail facilities, acreage, and proximity to load.

Water for condensing may, of course, be obtained at any site



Fig. 1—Map Showing Stations and Sub-stations.

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along the shore of the lake or banks of the river, and as these together comprise a stretch of sixty miles within the city limits, the probabilities of finding a satisfactory location are encouraging.

Along the entire lake front there are no railroads available, except from the mouth of the river south to 49th Street, and this entire frontage is occupied by the I. C. R. R. Many railroads cross the Calumet and, outside of the downtown district, railroads parallel both sides of the Chicago River except along the north branch north of Diversey Boulevard. So far there is plenty of latitude for choosing a site. But when we look for a 75-acre tract of land we discover at once that it will be necessary for any buyer, not vested with the right of eminent domain, to go far out from the business district where unimproved acre property is still available. Such property may be found along the Calumet and along the south branch of the Chicago River west of Ashland Avenue, but there is none along the north branch adjacent to rail and water.

On the map the locations of stations and sub-stations are indicated by squares, the areas of which indicate relative load, and which show where the load is and what stations are supplying it. An inspection of the map shows at once the undesirability of a location for a power house of the size contemplated, either on the Calumet or on the canal west of Ashland Avenue, the former because of distance from the load and the latter because it would be, in effect, an extension of existing power houses. We will, therefore, look again along the north branch, and here on the Chicago River north of Roscoe Street is a 55-acre piece, the remains of the old Bickerdike farm. The C. & N. W. Ry. is nearly a mile distant from the river, but the intervening space is occupied by the Bickerdike tract, two blocks of dwelling houses, and a 40-acre truck garden.

This situation at once suggested that the two pieces of property and a connecting right-of-way be bought and a private railroad be built connecting with the C. & N. W. Ry.; that the power houses and a secondary coal storage be located on the tract near the river, and that the principal coal storage and the trackage for car storage be located on the other tract. Such was the solution of the problem. In some respects the location is not ideal, but it is the best one obtainable.

The land acquired lies between Roscoe and Addison streets, and between the river and the C. & N. W. right-of-way, but within these boundaries is a tract comprising several blocks which are built up with cottages and two-story dwelling houses, across which tract a right-of-way was purchased for an elevated railroad.

An aggregate of 240,000 kw., or 350,000 horse power, in one building creates possibilities for an interruption to the entire supply. It was, therefore, deemed prudent to divide this capacity between two separate power houses of equal size, to which plan the

power house site is well adapted, as shown by the plan given in Fig. 2.

Since the purchase of the 53 acre tract of land on which the power house is located California Avenue has been opened, cutting the land in two, but as this probability was foreseen, the station's coal pile and trackage were located west of California Avenue, so the plans were not disarranged by the opening of the street.

Figure 3 shows the outline of the two power houses, facing on California Avenue, and symmetrically arranged on either side of a central east and west axis. Each has its system of railroad tracks and each has a large coal storage field spanned by a gantry crane 265 ft. long.

Water for condensing is drawn from the river through a double-deck tunnel, the upper conduit being used for the outflow, which is discharged into the river at a point several hundred feet down stream from the intake.

In dry weather the natural flow of the north branch is relatively insignificant. The greater part of the flow is pumped from the lake into the sanitary canal at Wilmette, and a smaller quantity is pumped from the lake through the Lawrence Avenue conduit. The Wil-



Fig. 3—Perspective View of Completed Station.

mette pumps are motor-driven, with electric power supplied from the Sanitary District power house at Lockport. Should this power be interrupted and the Wilmette pumps stopped during a time the station is carrying a full load, the flow of the river would not be equal to the amount pumped for the condensers. It would, therefore, be necessary to pump a portion of the discharge around and through the condensers a second time, and at a higher temperature and with some impairment of the vacuum.

If the Wilmette pumps and the Lawrence Avenue pumps were stopped at the same time, the river in a few hours would become too hot to be of use for condensing. Then, to minimize as far as possible the embarrassment which would result in the most improb-

able coincidence of a long shutdown of both the Wilmette and Fullerton Avenue pumps during dry weather and at time of full load on the station, the intake tunnel is made to draw its water from the bottom of the river at a point some distance up stream from the warm water discharge, thus using for a time the river as a storage reservoir and a cooling pond.

By the terms of the city ordinance under which the company built its coal track over the public streets and in a residence district, electricity must be used for motive power, and to comply with this provision the company has purchased two 60-ton electric locomotives and has already equipped three miles of track with a third rail. These locomotives were built by the General Electric Company and are of the type used by the N. Y. C. R. R. in its New York City terminal. They each have four 200 h. p. motors with 7-series and 5-series parallel steps.

Although the track over which these locomotives now operate is equipped with a third rail, it is recognized that in a crowded switch yard an overhead supply of power may be preferable, and for this reason each locomotive is equipped with a pantagraph trolley.

The design of the Northwest Station is, in general, similar to that of the Fisk Street Station and consists essentially of a turbine room 70 ft. wide and 290 ft. long, on one side of which is the boiler house, in which the boilers are arranged in rows of ten, one row opposite each turbine. Each of the two Northwest Stations is designed for six turbines and sixty boilers. On the side of the turbine room opposite the boiler room are the transformer house and the switch house, in separate though connected buildings.

About two-thirds of the first station building group has been completed, although only one-third of the equipment has been installed.

Cars containing coal, when delivered at the station, are run onto tracks over the receiving hoppers under the boiler room. There the coal is dumped into the first receiving hoppers and from there it passes through the coal crusher and into the conveyor, which elevates it to the second receiving hopper above the firing floor in the boiler room, from which second hopper it is drawn by gravity, as required, to the stokers in front of the boilers. If the coal cars have drop bottoms, the unloading is quickly done by opening the drops. If a car does not have a drop bottom, it is unloaded at a cost of 2c a ton by a 2-yard clam-shell bucket operated from an overhead crane.

In its passage through the boiler house the coal is handled on five different levels and in nine operations, as follows: Delivered on the unloading track, dumped into first receiving hopper, run through crusher, discharged into conveyor, elevated to second receiving hopper, drawn off to stokers, dumped from back end of chain grate to ash hopper, discharged into empty coal cars, hauled

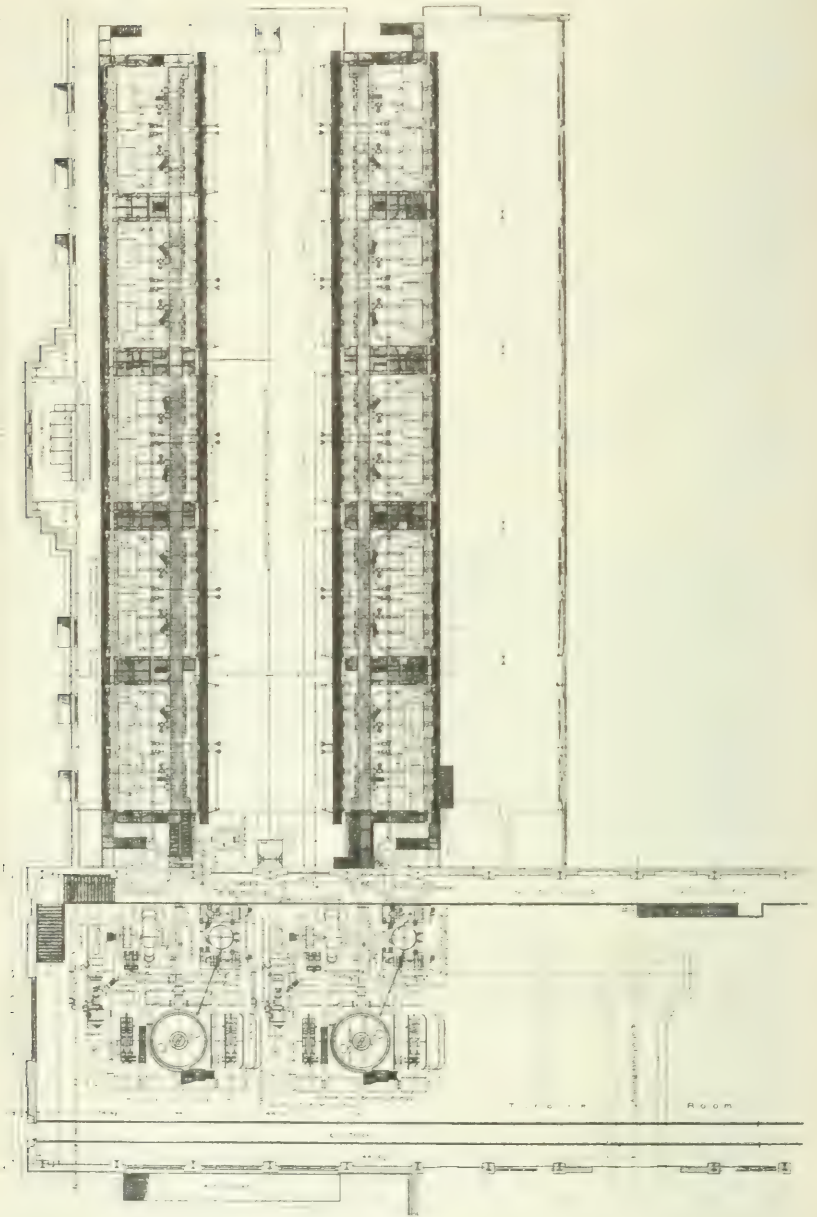


Fig. 4—Plan of One-half of Entire Plant as Designed.

out of train shed. The boiler house is so designed and equipped that at no point in the handling of the great volume of coal that daily passes through it is it necessary to use manual labor.

The boilers are arranged in rows of ten each, facing each other on opposite sides of a common firing room, so that one set of firemen and water tenders can look after twenty boilers. Each ten boilers are served by a tile-lined steel stack 17 ft. inside diameter and extending 275 ft. above the boiler room floor.

In designing the boiler furnaces it was recognized that they must burn the smokiest kind of soft coal screenings practically without smoke, for the stacks of a great public service corporation, that rear their proud heads 275 ft. above the sky line, are shining marks for the censorious.

The fundamental principle in smokeless furnace design is to provide a chamber of high temperature and of sufficient length or volume to insure complete combustion of the luminous flame before it comes in contact with the boiler tubes. This can be done perfectly in a furnace having a tile roof, but unfortunately two other things, both undesirable, are also accomplished. The changed gas passage restricts the draft and reduces the boiler capacity; at the same time the furnace temperature is so high that the expense of maintaining furnace walls and arches is greatly increased.

In the design used at the Northwest Station the boilers were set with the high end of the sloping tubes to the front and 10 ft. above the grate, the expectation being that this great height would serve as a vertical combustion chamber, with ample capacity to give the flame time to burn out before it reached the tubes; the draft would not be restricted and the brick work would be conserved by the temperature being kept down through the absorption of radiant heat by the exposed tubes.

The second battery of boilers were set like the first, with the exception that they were given a horizontal gas pass, the purpose being to give the two designs thorough comparative tests and adopt for the station that design which, all things considered, proved to be the best.

Each boiler should be able to easily generate 30,000 lb. of steam an hour, or 70% more than normal rating, and this rate of steaming will require a rate of coal burning of 4500 lb. an hour under each boiler, or 75 lb. a minute. This means that in each second of time 300 cu. ft. of air passes through the grate and in the heat of the furnace becomes 1500 cu. ft. It, therefore, whisks itself into and out of the furnace at a rate which necessitates combustion to be almost instantaneous if complete.

With sixty boilers all running at the maximum rate, the amount of air entering the grates each minute is over 1,000,000 cu. ft. If this were all drawn through the boiler room on a winter day, the firemen would be obliged to go out of doors to get warm; but to avoid such unpleasant draughts of cold air as would otherwise be

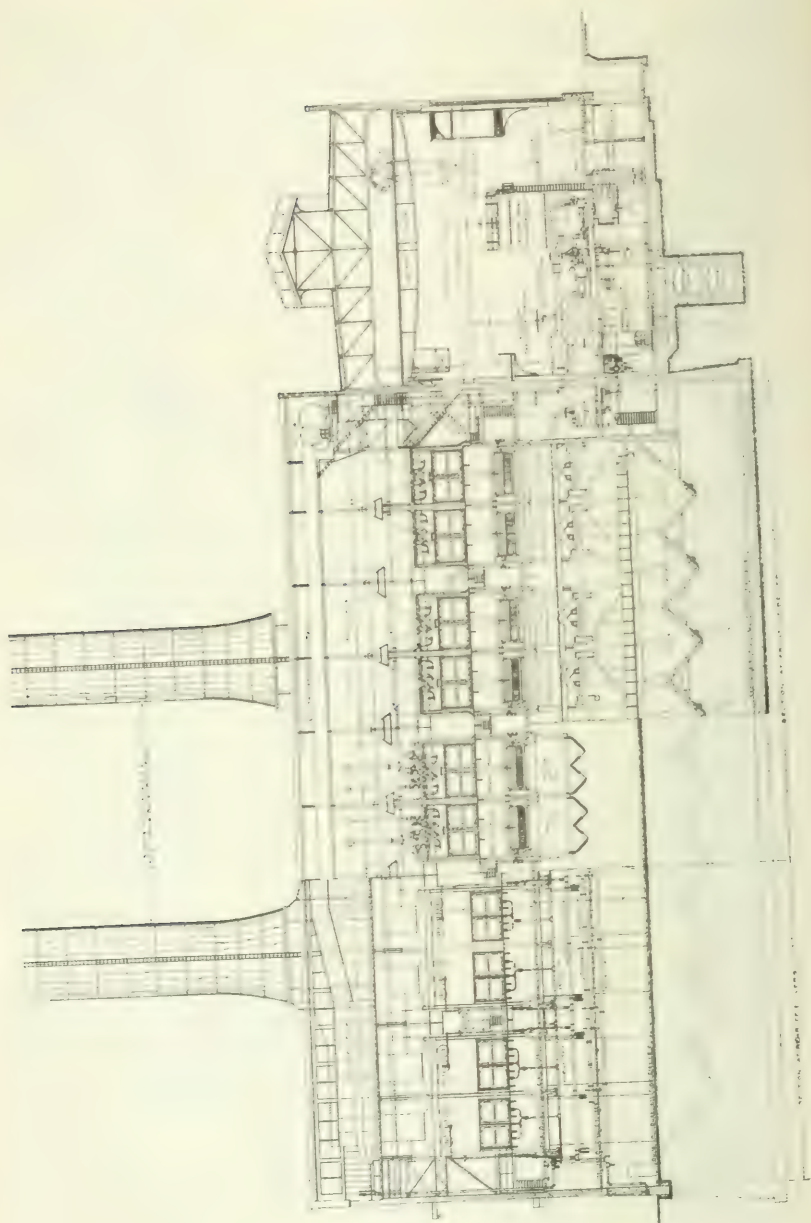


Fig. 5—Longitudinal Section of Plant.

created, provision is made to admit air directly under the grates from the train shed below.

These boilers have each 5,800 sq. ft. of water heating and 350 ft. of steam superheating surface, and are equipped with traveling chain grates of 115 sq. ft. area. Steam is raised to a pressure of 250 lb. and is superheated 125 degrees.

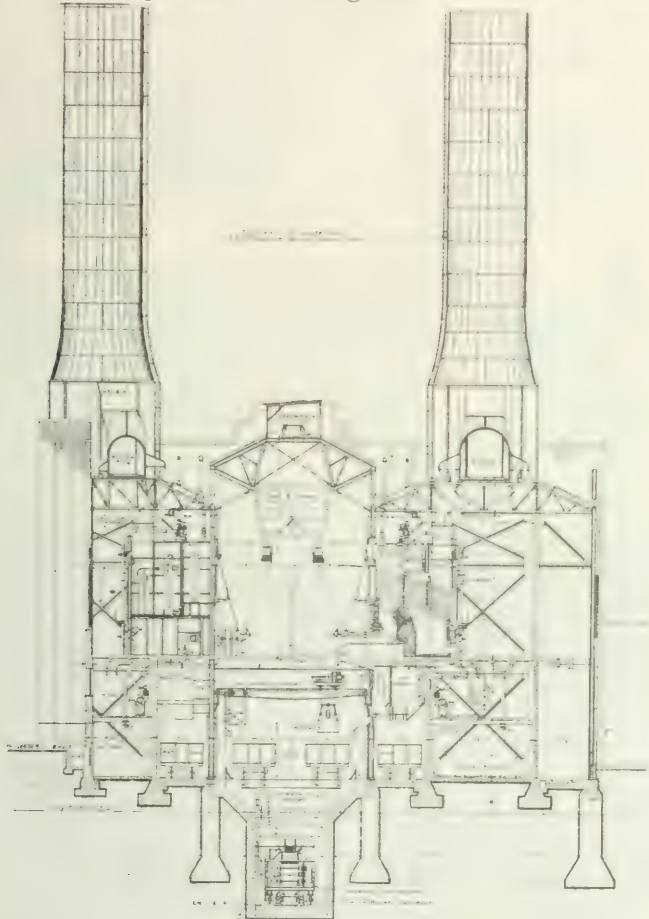


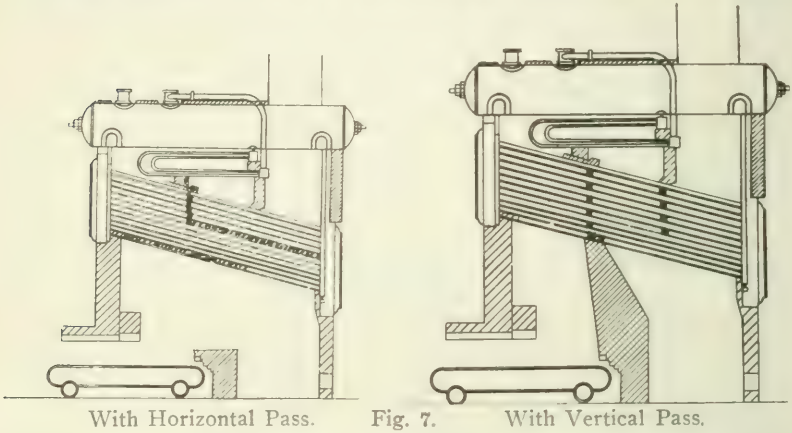
Fig. 6—Cross Section of Boiler Room.

Steam is taken from the boilers through 6-in. pipes connected with a 16-in. header supported on roller bearings in the header room. Connecting the steam headers is an 8-in. crossover, by means of which steam from one unit may be supplemented with steam drawn from an adjoining unit.

The safety valves of the boilers blow off through vertical ex-
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haust pipes leading to the roof, thus eliminating the danger and discomfort of steam at high pressure discharging into the boiler room.

Each battery of boilers is provided with two boiler feed pumps.



These are 5-in., 3-stage Worthington centrifugal pumps driven by Curtis steam turbines at 2300 r. p. m., and have a capacity of 700 gal. per minute against a pressure of 285 lb.



Fig. 8—Boiler Room.

The feed water is pumped from the condenser at a temperature of about 75 deg. into a closed feed water heater of 4000 sq. ft.

heating surface in which it is heated by exhaust steam from the auxiliaries. A float valve at the top of the heater regulates the admission of make-up water into the condenser.

The turbine room is finished in white enameled brick and when completed will measure 290 ft. long, 70 ft. wide, and 55 ft. high. This allows for a turbine spacing of 44 ft. from center to center. As the turbines measure only 15 ft. 5 in. maximum outside diameter, there is ample floor space for the auxiliaries. Compared with the Fisk Street Station, in which the units are of 12,000 kw. capacity and on 4-ft. centers, the floor space required per kilowatt at Northwest Station is considerably less. Spanning the turbine room is a Morgan traveling crane of 110 tons capacity.

The turbines are of the well known vertical Curtis type, similar to those in the Fisk and Quarry Street stations, are rated at

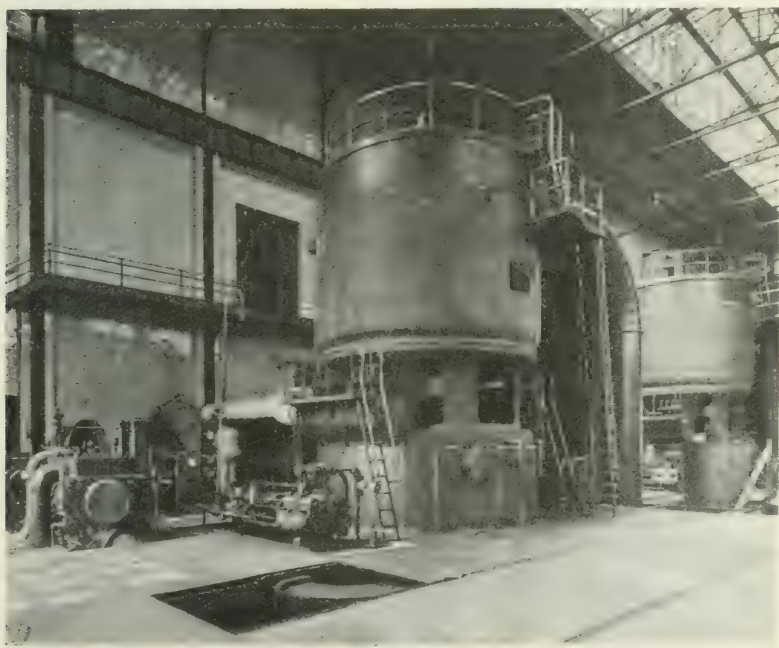


Fig. 9—Turbine Room.

20,000 kw. capacity, and run at 750 r. p. m. They are 6-stage, each wheel having two rows of buckets built in sections and riveted to the disk which forms the central part of the bucket wheel. The first three wheels have 28 double bucket sections of 24 buckets each, and the last three have 28 double bucket sections of 20 buckets each, making a total of 7392 buckets. These buckets vary in length from $1\frac{1}{4}$ in. in the top row of the first wheel to 18 in. in the bottom row

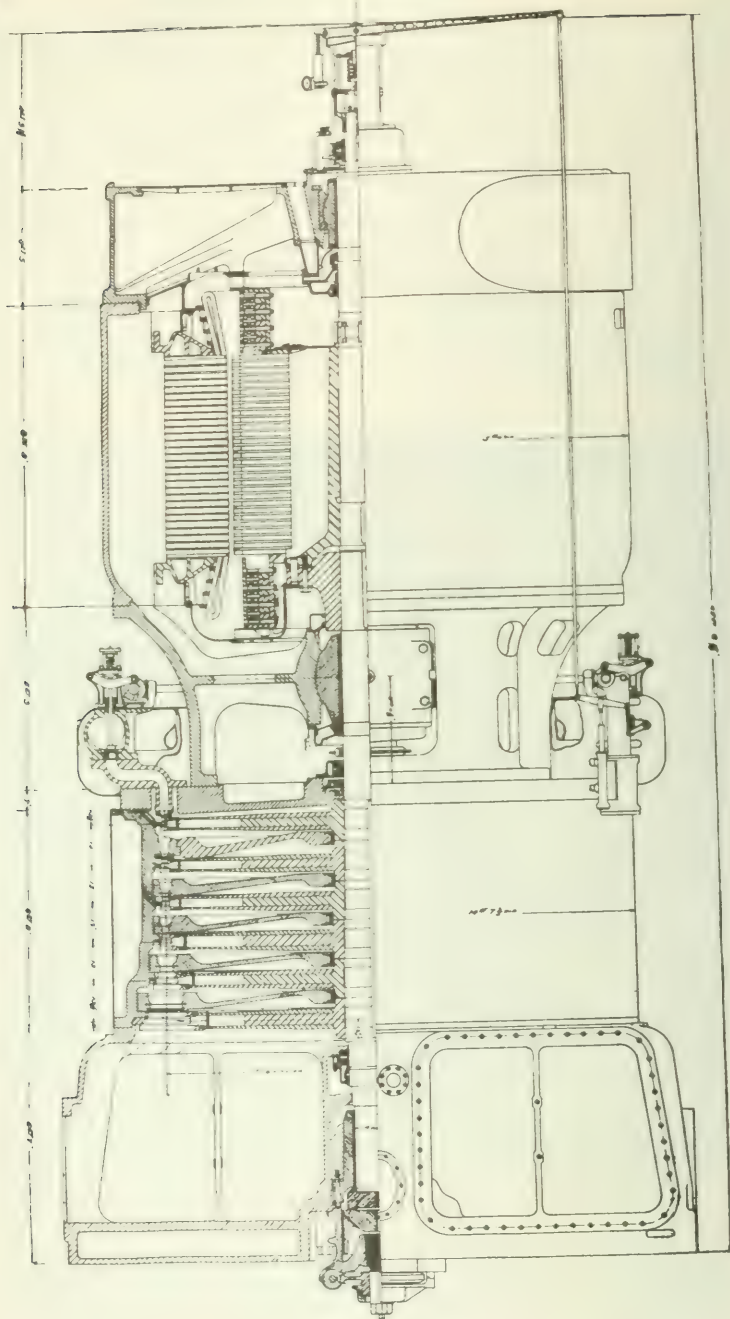


Fig. 10—Curtis Steam Turbine.

of the sixth wheel. The outside diameter of the sixth wheel is 13 ft. 2 in. and, therefore, has a peripheral velocity of over 500 ft. per second, or about 6 miles per minute.

The guaranteed steam consumption, with steam at 250 lb. pressure and 100 deg. superheat, is 14 lb. per kw. hr. at loads of 10,000 and 20,000 kw. and 13.45 lb. at a load of 15,000 kw.

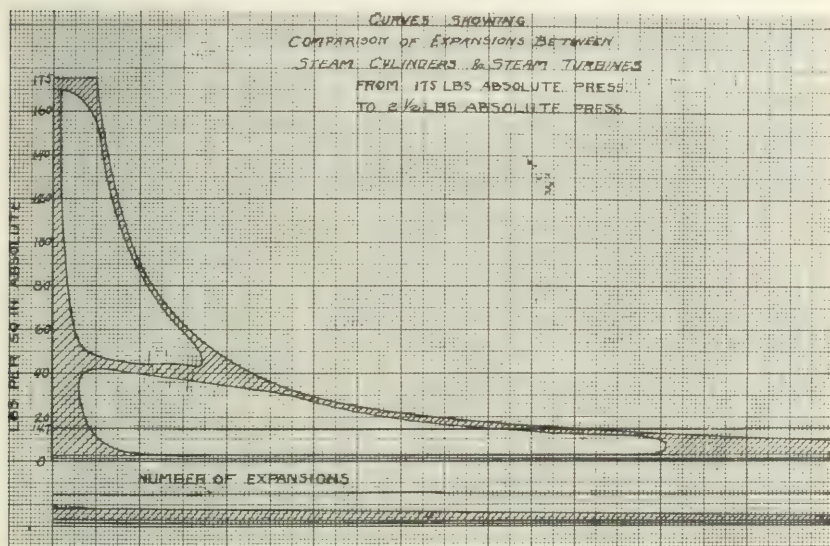


Fig. 11—Indicator Diagram.

It might be of interest to compare for a moment the action of steam as it passes through the cylinders of a reciprocating engine and the action of steam as it passes through the buckets of a steam turbine. Fig. 11 shows the combined indicator cards from a high and a low pressure cylinder of a reciprocating engine, using steam at 175 lb. pressure, expanding it to sixteen times the original volume, and exhausting at 10 lb. absolute pressure into a condenser of 25 in. vacuum.

The areas of the cards are shown shaded, and above these areas is drawn another expansion line, the area between which and the line of absolute zero pressure represents the potential work of that same volume of steam had it been used to the best advantage.

It will be seen that there are some losses due to cylinder condensation and to friction through exhaust ports, but the greatest loss of all is that caused by not expanding the steam down to lower pressures and greater vacuum, both in the high pressure and in the low pressure. Any increase in the amount of expansion in

this case is inadvisable, first because of practical limitations in the size of the low pressure cylinder, and second because of the excessive rate of condensation which occurs when there is great variation in temperature due to a higher number of expansions, and which limits these expansions to about four volumes in the high pressure cylinder.

By an inspection of the low pressure cylinder card it is seen that the area below the line of atmospheric pressure is relatively considerable, and amounts to about one-fourth of the entire area, which means that the condenser enables us in this case to get about one-third more work out of the steam than we would otherwise have obtained. But great as this amount is, it is less than half what would have been realized had we been able to expand the steam along the theoretical expansion line, which is shown in the same figure.

It also is apparent that if the vacuum in the case of this engine were reduced by 1 in., the efficiency of the engine would have been noticeably impaired, but very much less so than would have been the case if the expansion were theoretically complete.

From Fig. 10, which shows in section the arrangement of buckets and their relative lengths on successive rows, it is seen that these lengths are proportioned to the expanding volume of the steam as it passes through the blading, and that by merely adding additional rows of longer blades this expansion may be carried to any extreme and finally discharged into the condenser chamber without any terminal drop in the exhaust, as is seen in the case of the card for the low pressure cylinder. This saves, in the case of the turbine, much of the area between the theoretical expansion curve, the line of condenser pressure, and the end of the low pressure expansion curve, which in the engine is lost.

With the much increased ratio of expansion which is obtained in the turbine, it is seen that the importance of low vacuums is much greater with the turbine than with the engine, and for this reason unusual provisions, which in the case of the reciprocating engine would not be warrantable, are made in the case of steam turbines to carry the vacuum to the lowest point which the temperature of the cooling water will permit, and to this end we install with steam turbines condensers of double the area and supplied with double the amount of water that is the practice with steam engines.

Steam can be expanded from 200 lb. down to say 50 lb. pressure more economically in a steam cylinder than it can through the blades of the first stages of a turbine, but the loss through the low pressure cylinder is so great that the combined efficiency of all the stages of a steam turbine is much better than it is through the two or more cylinders of a reciprocating engine.

In Fig. 12 is a curve which shows the variation in the percentage of the energy of steam which would theoretically be avail-

able with various condenser temperatures. The enormous savings indicated suggest the advisability of proportioning the turbine blades for the lowest obtainable pressure, and using refrigerated brine for circulating water.

An engine with a 3-ft. crank and running at a speed of 75 r. p. m. would have an average piston speed of 900 ft. per minute, and the cylinders of the engine must be built large enough to accommodate the volume of steam which passes through them at that speed. In the turbine the steam has a velocity nearly one hundred times greater, and, therefore, in spite of the greater expansion which is obtained, the cubical space which must be provided for steam in its passage through the buckets is only about one-fiftieth as much as would be necessary in the case of steam cylinders doing the same amount of work. As in the case of each of these prime movers the determining factors as to size are the

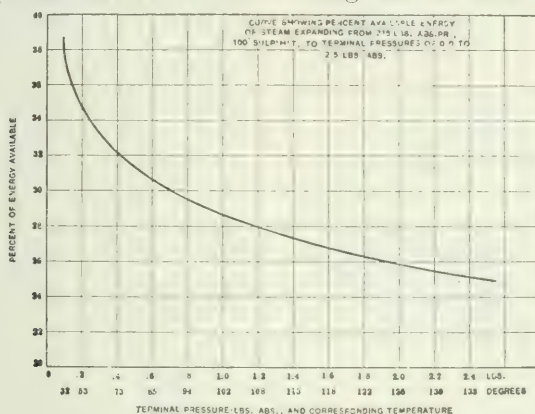


Fig. 12.

Available Energy with Varying Condenser Pressure.

dimensions of the steam space, it is at once apparent why, aside from economy, the turbine has so effectually run the larger sized engines out of the market.

The weight of the steam end is 200 tons and of the generator 230 tons, making a total weight of 430 tons, of which 100 tons is in the revolving elements. This great weight is supported on the step bearing, the two halves of which are kept from direct contact by oil which is forced into the bearing at a pressure of 800 lb. per sq. in. to which the pump pressure of 1200 lb. is baffled down. Floating on this oil system is an accumulator weighted to 30 tons. Should the accumulator sink to a predetermined level, owing to failure of the steam pump, it would automatically put into operation an auxiliary electrically driven pump.

The base condenser on which the turbine rests is designed to condense 280,000 lb. of steam per hour, using for each pound of

steam condensed 75 lb. of cooling water, whose temperature will be raised 14 deg. F. in passing through the condenser. The condenser contains 7600 1-in. tubes 17 ft. long, comprising 32,000 sq. ft. of cooling surface as compared with 58,000 sq. ft. of water heating surface in the boilers. A 20 x 30-in. Corliss engine, running at 120 r. p. m., drives the circulating water and dry vacuum pumps. The circulating water pump is a 36-in. volute of a capacity of 40,000 gal. of water per minute against a head of 20 ft. The condenser with its inlet and discharge pipes form a closed syphon, so that after the system is once filled with water the lift in one leg is balanced by the fall in the other, and then the circulating pump has only to overcome the friction and inertia to circulate the water.

The cylinder of the dry vacuum pump, which is mounted in tandem with the steam cylinder of the Corliss engine, measures 28 x 30 in. and at the speed mentioned has a displacement of 2550 cu. ft. per minute. Such a volume of air drawn from a condenser having an absolute pressure of 1 in. would shrink to 80 cu. ft. at atmospheric pressure, or about 7 lb. of air.

Water of condensation is removed from the condenser by a 5-in. horizontal 2-stage Worthington centrifugal turbine-driven pump with a capacity of 660 gal. of water per minute.

The generator mounted above the turbine is of the revolving field type and generates 25-cycle, 3-phase current at a pressure of 4500 volts, which is stepped up by transformers to 9000 volts. The revolving field has four poles and weighs 52 tons. The armature is star wound and has a continuous rated capacity of 2570 amperes per phase.

The peripheral velocity of the turbine-driven revolving field is five times as great as in the case of the reciprocating engine, and the amount of work done per unit of mass for the whole field is proportionally increased. Moreover, the barrel-shaped armature in which the turbo-generator field revolves does not permit of the natural ventilation which occurs in the case of an engine-driven field of large diameter revolving in almost free air. For these two reasons forced ventilation is necessary with a turbo-generator, and is created by a fan mounted on the main shaft above the generator and set to blow a strong blast of air through the field and armature. The efficiency of the generator is very high (96%), and yet because of the great amount of energy transformed in the generator, the heat evolved is equal to that resulting from the perfect combustion each hour of 270 lb. of coal of the quality that is used in the boiler room.

The capacity of a generator is limited by the temperature of its insulation, and may be increased as means for keeping down the temperature of the insulation are improved. To render the relatively small turbo-generator safe with the great loads which

are put upon it, the air for the forced ventilation is drawn not from the turbine room, but from outside of the building.

For excitation purposes 75 kw. at 125 volts is required.

In the completed station there will be four exciters. Two of these will be of 300 kw. capacity each, driven by a 2-stage horizontal Curtis steam turbine running at 1500 r. p. m. and generating current at 125 volts. The other two, of 200 kw. capacity each, will be driven by 3-phase, 25-cycle, 220-volt motors running at 750 r. p. m.



Fig. 13—Operating Gallery.

In addition there will be two storage batteries of 70 cells each, with a capacity of 1000 ampere-hours.

The operating gallery is located in a bay projecting into the turbine room, and from here the operator has a clear view of the entire turbine room floor. The generator control switches are mounted on a bench board, and the line control switches and all instruments are mounted on vertical slabs above the bench board.

Slow speed engine-driven generators, by their mass and construction, have inherently such poor automatic regulation that any sudden reduction in the resistance of the circuit supplied is accompanied by an increased output of current at a considerably reduced pressure. This is due to the choking or reactance effect

of the armature. This feature of such generators resulted in serious fluctuations of pressure with fluctuation of load, and was naturally considered an objectionable quality. Central station managers were, therefore, continually asking manufacturers for machines having better inherent regulation.

With the advent of the high speed turbine it was found possible to build a generator whose reactance was only one-fourth or one-fifth of that of the slower speed generators. This was thought to be a highly desirable improvement, and the utmost advantage was taken of the new design to keep the reactance as low as possible. But when such generators of large sizes were built and connected to a common set of bus bars, it was found that nearly the whole energy stored in the high-speed revolving masses would be instantly hurled into any near-by short circuit which occurred, the energy output of the machines for the moment being perhaps twenty times normal.

Such violent surges were so destructive to generators, switches, bus bars, lines, and connected apparatus that it was found necessary to restore to the circuit nearly as much reactance as had been gladly eliminated. In the case of the Fisk Street machines, this was accomplished by installing in each of the three armature leads to the bus bar a 6% reactance—that is, a coil of wire supported on a concrete and wood frame, whose choking effect, together with the 2% reactance in the generator, at full load of the generator is equal to 8% of the voltage generated. This effect, which is unobjectionable at normal loads, increases with the square of the current flowing and, therefore, in times of trouble affords protection which is ample and at the same time automatic. In fact, one of the 12,000 kw. Fisk Street generators was repeatedly short circuited through a set of these reactances without harm to generator or coil.

At the Northwest Station the additional reactance needed was introduced into the circuit in the auto-transformers, which step up the pressure from the machine voltage of 4500 to the system voltage of 9000. These transformers are installed in a separate building, between the turbine room and the switch house.

Each transformer is installed in a separate fireproof compartment and is of 3333 k. v. a. capacity. They are water- and oil-cooled and contain 1700 gallons of oil. Water is circulated through pipes immersed in the oil at a rate of 16½ gallons per minute. Each tank has an emergency drain, by means of which it can be emptied of oil in a very short time.

The efficiency of these transformers is very high, being 99.4% at half load and 99.3% at full load. They are 13 ft. high, 9 ft. long and 5 ft. wide, and weigh, with the oil, 25 tons.

To the east of the transformer house is the switch house, a three-story building containing all the oil switches, high tension bus bars, and instrument transformers. On the first floor the bus bars, cables, bells, and generator leads are installed. The line and

generator buses run east and west, and the main and auxiliary buses north and south.

The second floor contains the oil switches, the pots of which are built in a single row instead of a double row. This arrangement provides greater safety, in that each oil pot is separated from the adjoining one by a concrete partition.

Nineteen switches are provided for each unit, nine of which are line switches, eight are bus and tie switches, and two generator switches.



Fig. 14—Auto-Transformers.

The generating station just described is the most modern of any in existence, and was designed by engineers who have been engaged all their lives in designing power houses and power house equipment. No expense was spared to make this installation the last word in the art of converting the energy of coal into electrical energy. The station was designed for six units, two of which were

to be included in the first installation and the remaining four to follow soon thereafter, so that the station when completed would contain a symmetrical, up-to-date equipment of the largest size and highest efficiency; but alas for the best laid plans of men—between the dates that the plans were finished and the station was put in service, as great strides were made in the art as had been made during any period of equal length in its history. The Northwest Station is doing all that was expected of it, but within a little more than a year from the time it was put into service its equipment will be eclipsed by an installation at Fisk Street of larger and more efficient boilers, and larger and more efficient turbines.

The indications now are that the equipment which will be installed at the Northwest Station in the future will be of an entirely different type from that now in, and we may even hope it will be as great an improvement over the newer Fisk Street turbines as those are expected to be over the machines we have discussed tonight.

DISCUSSION.

Bion J. Arnold, M. W. S. E.: We all know that Chicago has led in central station design. This is due to a combination of conditions and circumstances that cannot, I think, be excelled anywhere on the globe. Among these are: First, a very broad conception of the management of public utilities on the part of the head of the great organization which has recently erected this station. Second, the engineering talent which that organization has been able to regularly command. Third, the ability of the consulting engineers who designed the station, and who, as the author has well said, have practically spent their lives in the design of central station work.

Personally, I feel a little out of place in attempting to discuss the subject of central station design, for while at one time I thought I knew something about the subject, having spent many years in that kind of work, it has been some years since I have paid much attention to it, so far as the detailed design is concerned. I have been occupied, in recent years, chiefly in endeavoring to be instrumental in harmonizing conditions between the public and the central station and railway companies of the country, so as to enable the companies to live and at the same time see that the citizens get their just deserts. For that reason I have lost, to a certain extent, some of the knowledge of detail, and of scientific application of that knowledge to central station design, which might interest you if I could discuss it more minutely.

Some years ago I delivered a course of lectures on the subject of central station design, or electric power station design, and now have a contract with a certain publisher in this country for the publication of those lectures in the form of a book. That contract has been in existence for about ten years. I once heard

of a wise man who instructed an author as follows: "Young man, if ever you write a book, put that book in the drawer of your desk and let it lie there for ten years; then, after that length of time, read it, and if you think it is worth publishing, publish it." The manuscript of my lectures still lies neglected in a drawer of my desk. Had they been published soon after being delivered, the information would have been very much out of date today.

At that time the efficiency of our steam-driven electric plants was from 5% to 6%. I am speaking of the thermal efficiency; that is, the efficiency between the heat units in the coal and the electrical energy delivered upon the bus bars of the station. We came gradually to 6%, 7% and 8%. The Fisk Street Station, with the first turbines installed, would probably have given a thermal efficiency of 7% or 8%. The next large ones to be used were installed by the New York Central Railroad Company, with which I had the privilege of being connected, and we, as engineers, did the best we could at that time. We obtained an efficiency of about 9%, as I recall it. Then came improvements in the Fisk Street Station. They raised the efficiency there to in the neighborhood of 10%, I think. That is about as high a thermal efficiency as can be obtained today in a moderate sized turbine station, that is, with units of from 8000 to 10,000 kw. capacity. I doubt if that efficiency can be obtained with 5000 kw. units, but it can be obtained with 10,000 kw. units. In plants of, say, 10,000 kw. capacity and above, by means of a combination between the most modern reciprocating steam engines and low pressure turbines, a slightly higher thermal efficiency can be reached, and a little over 11% has been obtained by one of the New York stations with this combination. I am not sure that this efficiency can be reached or exceeded by the Northwest Station, as I do not know just what efficiency they expect to get, but when such efficiencies can be obtained by means of the combination of reciprocating engines and low pressure turbines, the fixed charges on the increased investment necessary for such a plant over the modern steam turbine plant will usually fully if not more than offset the advantage of the increased efficiency; consequently the combination is seldom used except in cases where reciprocating engines have been first installed. But with the coal as used here in Chicago, having a little less than 10,000 B. t. u. per lb.,—a poor grade of coal,—and with 20,000 kw. units, I surmise that this station ought to secure something over 10%, or in the neighborhood of 11%. If it does that, it will produce electrical energy cheaper than any other place I know of in the world, where electrical energy is produced by means of coal. In fact, I think that energy is today being produced here cheaper than in any other place in the world where it is produced by means of coal.

I am very glad to have the author state that notwithstanding the galaxy of talent that was brought to bear upon this great sta-

tion, even these engineers are going to outdo themselves in the next edition of the Fisk Street Station, because that exonerates to a large extent, I think, those of us who had to do with the original installation of the New York Central Railroad, and for which some of us have been criticised, due to the fact that these critics said our station and our system would be obsolete before it was placed in operation. If such engineers as those who have designed this station get in the same class, and are not ashamed of it, I am no longer going to be ashamed of our record; in fact, I never have been ashamed of it, for we did as these engineers have done, namely, built the best we could with the machinery available at the time.

I used to know something about the design of reciprocating steam engines,—the pressure which could be allowed on their various parts. I believe one could go as high as 1200 lb. per sq. in. in locomotive practice on pin bearings; to 400 lb. per sq. in. on main bearings in marine practice, and somewhat higher in stationary practice; and when using mild steel we could strain bolts up to 1200 lb. per sq. in. of cross section. Many of those things I knew, but they are of little use now, because in the design of turbines they are almost all lost, as we have no reciprocating parts and no piston or cylinder head bolts to worry about; only a few highly-strained revolving parts are to be maintained. We get into a different line of work, and unless we are following the particular line described here tonight, we are hardly in position to speak intelligently of detailed design. I did recognize, however, in the description, many new ideas, and I may say good ideas inasmuch as they are toward simplification of power station design.

Fifteen or twenty years ago the manner of designing power stations was extremely complicated. We then thought it necessary to have all kinds of supplemental auxiliary parts, such as variable speed, electrically-driven boiler feed and condenser pumps, various kinds of economizers, storage batteries, auxiliary piping, etc., many of which are still useful in their proper places. But we have come to the point where we have eliminated the duplicate set of piping and elaborate system of lubrication due to the many joints incidental to the reciprocating engine, duplicate set of valves, and a lot of other paraphernalia, in order to be sure that none of our prime movers shall be put out of service. We now install independent compact units and depend upon a single set of piping and valves to keep them going. In case of an accident to one of them we depend upon the overload capacity of the units that are not disabled to carry the load while the break is being repaired. In the plant described, we note that they have two large units to start with, but of course they are reinforced or rather supplemented by the fact that the company has two other large stations in the city, which can be cross-connected with this station in case of a breakdown. In that respect it is exactly the same arrangement

that we laid out for the New York Central Railroad some ten years ago. We planned there two large central stations, one in the southern part of the city and the other to the north. With those stations inter-connected, we believed we would be ready for almost any emergency that came as far as shortage of power was concerned, and that being a pioneer installation in the electrification of steam railways we felt we could take no chances on being short of power. We were not in position to purchase power from the New York Edison Company, as that company could not then make a satisfactory price; therefore, we had to install our own power plants to make the energy cheaply and to be sure of our power. The latter reason was the cause for the installation of two stations, and both of those stations would have been in operation long before they were had it not been for the fact that financial matters, relating to the elevation of the company's tracks through the municipalities in the vicinity of New York, caused delays which made the completion of the electrical installation of the road slower than was originally anticipated. So that today, due to the development of the art of manufacturing and selling power on the part of the central station companies,—and the precedent was set by the Commonwealth Edison Company here,—the New York Edison Company is discussing with the New York Central Company the question of taking over one or possibly both of those stations, for the purpose of operating them and selling power to the New York Central, as well as other companies in the vicinity. Thus they will endeavor to prevent the duplication of investment which would be necessary if they built a new station to take care of their growing business. That is exactly what has happened in this city. The Commonwealth Edison Company has foreseen and acted upon the great economic principle of not duplicating investment in a community, and is making propositions to the great power-using corporations of this city. Those propositions are sufficiently attractive to warrant corporations purchasing power from this company rather than build their own plants, and at prices which are as cheap or cheaper than those at which companies can produce power. Under those conditions it is wise to purchase power.

G. T. Seely, M. W. S. E.: From the view-point of a railroad man, the number of miles of track shown by the author impresses me, as well as the fact that in a commercial undertaking of this kind so many features had to be taken into consideration, aside from the matter of generators and boilers. For instance, the amount of ground necessary. Ordinarily in power house construction one figures so many square feet per horse power. According to the author's figures, it is more the number of acres per kilowatt or the number of miles of track per kilowatt.

The installation of a third rail railroad is interesting, and I believe that is the first installation of protected third rail in this

part of the country. I would ask the author how it has worked out,—if there is any difficulty?

Mr. Abbott: We have not heard a word from it since it began to be operated.

A Member: Has any precaution been taken to prevent spontaneous combustion of the coal when stored in such large piles?

Mr. Abbott: Nothing has been done, and so far as we know nothing can be done, except to store coal which is not liable to spontaneous combustion. That means coal in large sizes, if Illinois coal is used. Fine coal screenings will be sure to take fire if stored during warm weather, or if kept during warm weather. The only protection is to store screened coal of somewhat larger sizes.

STREET CLEANING IN DOWNTOWN CHICAGO

RICHARD T. FOX.

Presented December 2, 1912.

Street cleaning results in Chicago on the whole have always been open to criticism, principally because the needs of its tremendous street area have been so much greater than the appropriations for the purpose could possibly satisfy. The streets in the principal business areas of the city, which, on account of the heavy traffic and other sources of dirt, are the most costly to clean, have suffered more from lack of proper attention than any others. With a desire to improve the condition of the streets in the central business district of the city, the Commercial Club and the Merchants Club—two organizations formed to forward the interests of the city at large—organized a Citizens' Street Cleaning Bureau in June, 1904. The results that have been secured since then by this bureau are noteworthy, as the streets covered by its forces have been kept clean at all times, notwithstanding the character of the paving and the difficulties of cleaning it.

The area now covered by the bureau embraces fifty-two city blocks with the corresponding streets and alleys, which include 118,975 square yards of street surface and 18,000 square yards of alley surface, making $4\frac{1}{4}$ miles of streets and 1.6 miles of alleys.

The bureau has two sources of income. The city pays it, under a contract, \$36,000 per year, this sum being the proportion of the city funds that the officials estimate would be spent on the street area mentioned above if the city did the work. That amount is not sufficient to maintain the high standard of cleanliness set by the bureau, so the remainder of the expense is supplied by a voluntary assessment against the frontages of the tenants and property owners in the district. This assessment is made on the basis of the actual cost of cleaning a particular frontage in which the traffic, kind of pavement, condition of pavement, and other factors are considered.

The method of providing for street cleaning by a private organization of this kind is believed to be unique, in this country at least.

The necessary executive officers and a board of directors are elected from the subscribers. At present they are as follows:

J. L. Kesner, Chairman; Frank L. Macomber, Vice-Chairman; Ogden T. McClurg, Secretary; F. H. Rawson, Treasurer; Richard T. Fox, General Manager.

DIRECTORS.

Bryan Lathrop,

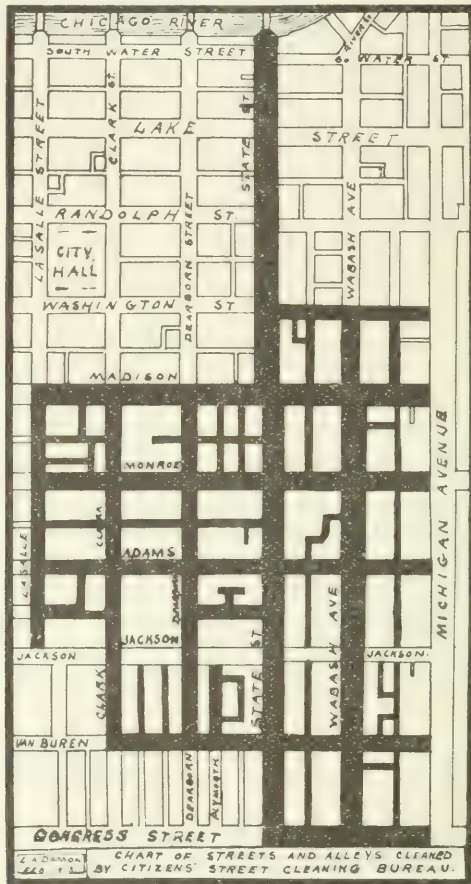
Ogden T. McClurg, President, A. C. McClurg & Co.,

C. D. Peacock, C. D. Peacock & Co.,

J. L. Kesner, Kesner Building.

February, 1913

W. D. Juergens, Juergens & Anderson,
 Francis W. Taylor, Aldis & Co.,
 W. H. Onderdonk, Manager Tribune Building,
 James Simpson, Vice-President Marshall Field & Co.,
 D. F. Kelly, Manager Mandel Bros.,
 F. H. Rawson, President, Union Trust Co.,
 Louis Stumer, Stumer, Rosenthal & Eckstein,



Frank L. Macomber, Hibbard, Spencer, Bartlett & Co.,
 Seymour Morris, Seymour Morris & Co.,
 J. H. Wood, General Manager, Carson, Pirie, Scott & Co.,
 E. M. Willoughby, Willoughby & Co.,
 Elmer Schlesinger, Mayer, Meyer, Austrian & Platt.

The operations of the bureau are in charge of a General Manager. An inspector immediately in charge of the foremen of

the sections into which the area covered is divided reports to the General Manager.

The sections are further divided into forty-two sweeping routes, the area of each of which depends on the width of the street, the kind of pavement, the density of traffic, and so forth. A man sweeping by hand is assigned to each of these routes which vary from one-half to two blocks in length, this man being held to account for the cleanliness of his route. The sweepers are uniformed and numbered and each man has a space at headquarters for his uniform and tools. To avoid confusion and to fix responsibility for the care of the bureau property, this space and each particular implement in the sweeper's care bears his number. The bureau also has its own teams and wagons for hauling sweepings to the dump, the drivers of these teams being uniformed and numbered the same as the sweepers.

The number of sweepers at work and the route covered by each man is followed from the office each day by a special system of checking. A board carrying a large scale map of the district with the different routes shown, and a lot of thumb tacks each having a number on the head, are provided. When the men report in the morning, a tack bearing the same number as the number on the cap of the sweeper covering each route is placed on the map. If any men quit work during the day, the office is notified and the tacks on their routes on the maps are removed. In this manner it may be seen with a glance at the map whether any routes are not covered. For the purpose of checking up the men actually at work, the auditors of the bureau are supplied with one of these maps.

The foremen make written reports daily of the number of men employed, the route swept by each man, the number of teams at work, the yards of refuse removed, and the condition of their sections at quitting time. The team reports cover the time required to make each round trip, including the time of collection and the return from the dump, and give the number of yards of refuse hauled at each load. If for any reason a street or a portion of a street is not thoroughly cleaned, or if any sweepings are left in the gutters at quitting time, these facts must be noted and explained in the foreman's report. No excuse short of a circumstance entirely beyond the control of the inspector and foreman is accepted for either of these conditions. Failures to perform the work assigned, or other delinquencies, are reported on a blank form with the name and number of the sweeper or driver concerned, and a recommendation not to exceed the punishment prescribed in a published code of rules, as to the disposition of the case, is forwarded to the office of the General Manager for final action. The daily reports are checked by the inspector who forwards them every morning with his own report covering the entire district, to the office of the General Manager. From these reports and from an

inspection of the streets, the General Manager is enabled to keep in close touch with the most minute details of the work.

A daily statement showing the cost, by sections, of the previous day's work is made out and by noon each foreman knows the cost of the work done under his direction as compared with that of the other foremen. The effect of this arrangement is to create a spirit of competition and rivalry, with a consequent beneficial influence on the character and cost of the service. The daily expense reports are made out by the inspector and are approved by the General Manager. They cover the cost of supervision and of labor for the sweeping, and the cost of supervision, labor and teams for the carting, the cost of administration, office and miscellaneous expenses being proportioned at the end of longer periods.

The streets are swept thoroughly every day, on an average of ten times each week day and five times on Sundays. The sweeping is done entirely by hand, which is, of course, a more thorough and effective method than machine sweeping, especially on the uneven pavements of the district covered. The hand cleaning can also be done during the day when it is most essential that the streets should be in good condition. The sweepings as they are gathered from the street surface are deposited in metal boxes placed along the curb edge of the sidewalk, for temporary storage between the rounds of the wagons, which are made from time to time during the day. These boxes have a handle on each end and are covered with a hinged lid. They hold about 4 cubic feet of sweepings and are placed at various intervals along the street, depending on the amount of sweepings obtained from the block. Although these boxes do not add to the appearance of the street, and interfere to a slight extent with the free use of the sidewalks, their use is far preferable to the practice of piling the sweepings in the gutter to be scattered by traffic, blown about by the wind, or washed along the gutter by a sudden shower.

The various elements of difficulty which affect the cost of street cleaning were carefully studied by Col. George E. Waring when Commissioner of Street Cleaning in New York, 1895 to 1898. It was found that there were streets of good pavement, light traffic, etc., where one sweeper could keep clean 20,000 square yards, while on other streets, in the crowded districts, it was one man's work to keep clean 1,000 square yards. In the first case it was necessary to sweep the pavement once only each day. In the latter case seven laborious trips were necessary, daily.

The thirteen factors which determine the cost of cleaning any pavement are described in Colonel Waring's report as—

- (1) Kind of Pavement.
- (2) Condition of Pavement.
- (3) Amount of Traffic.
- (4) Amount of Car Track.
- (5) Kind of Car Track Rail.

- (6) Amount of Sanding.
- (7) Amount of Sprinkling.
- (8) Elevated Railroads.
- (9) Character of Population.
- (10) Presence of Schools.
- (11) Existence of Markets.
- (12) Push-cart Stands.
- (13) Vicinity of Unpaved Streets.

The difficulties here mentioned with which the bureau has to contend in cleaning Chicago's congested downtown streets named in the order of their importance, are:

- (1) Amount of Traffic.
- (2) Character of Population.
- (3) Kind of Pavement.
- (4) Condition of Pavement.
- (5) Amount of Car Track.

A street that has heavy traffic is seen to have more influence on the labor of sweeping than has the kind of pavement. The amount of traffic affects the cost for four reasons:

- (1) Because of the amount of horse droppings.
- (2) Because of the dirt of one kind and another which comes from the wagons.
- (3) Because the passage of horses and wagons effects a solid packing into crevices of the dirt upon which they tread.
- (4) Because of the difficulty of giving close attention to his work when the sweeper must devote a considerable portion of his time dodging horses and vehicles.

Amount of Traffic: The effect of traffic on the cost to the bureau of cleaning the congested downtown streets may be illustrated by the fact that of the forty-two sweepers now employed, nineteen, or nearly half of them, are necessary because of continuous movement of horses and vehicles through the streets.

Character of Population: No other single cause contributes so much to the difficulty and expense of sweeping as the action of careless and thoughtless persons in making the public streets the receptacles of all kinds of rubbish of which they wish to be rid, and which a little consideration would induce them to deposit in the boxes provided for the purpose.

Modern pavements with impervious foundations should confine the dirt to be removed by the street cleaning force to the daily accumulation of horse droppings, the materials ground by traffic into the pavement, abraded metal, and to any purely accidental litter.

Let us see what this bureau has had to contend with in addition to the above, and what the additional cost has been.

The most notable class of preventable litter consists of newspapers, wrapping paper, paper boxes, fruit skins, excelsior, straw

sweepings from sidewalks and buildings, ashes, etc. The time consumed by the whole body of sweepers in gathering this litter from the streets amounts practically to the entire time of four men. This means then that \$180.00 per month, exclusive of cartage, is expended on this item.

Another source of litter which could be easily prevented is the dropping of materials from overloaded or loosely-jointed wagon boxes, such as sand, plastering, steam ashes, cellar dirt, broken stone, lime, brick dust, cement, gravel, sawdust, and in fact every kind of finely divided material carted through the streets.

The wagons hauling dirt from excavations for foundations and cellars, are responsible for a large part of this litter. The boxes are loaded above the sides, and the wheels pick up dirt as they are hauled out of the excavations, especially if the ground is wet. From these two causes the course of the wagon is marked for several blocks. We estimate that this violation of the city ordinance imposes on us an expense of \$90.00 per month.

Improperly-controlled building operations are the source of a great deal of annoyance and added expense. Beginning with the excavating and continuing until the last bit of material is in place, the adjoining street is in a dirty condition and on windy days the air is full of dust. No attempt is made to sprinkle or confine loose material, and the most ordinary provisions of the building permits are in many cases neglected. From observation and data obtained from block to block records of dirt collected, we estimate that the time of one man, or \$45.00 per month, is expended in keeping the streets in the vicinity of building operations in condition.

All of these three items, which amount to the wages of six men, are properly to be charged against the character of the population. In other words, of the forty-two men now employed, six are necessary because of the carelessness and indifference of the people who use the streets.

Kind of Pavement: The kind of pavement affects the cost because a rough pavement such as granite, brick, or other loosely-jointed blocks are more difficult to clean than a smooth pavement, such as asphalt, bituminous macadam, or creosote block.

In 1904 as much as 75% of the pavements in the district cleaned by the bureau were of granite blocks laid on earth foundations, and in wretched repair. Each year since 1907 some of the granite paving has been replaced by creosote block, until at present the granite block is only 38% of the total. This change in kind of pavement has enabled the bureau, within the past five years, to dispense with nine sweepers.

If the remaining granite paving were replaced by some smooth pavement, four more men could be dispensed with. In other words, four out of forty-two sweepers now employed are necessary because of the kind of pavement.

Condition of Pavement: No argument is necessary to show that a street in bad repair is more difficult to clean than one in good condition. If all pavements were in first class condition, the cost of cleaning would be reduced so that the same standard of cleanliness could be maintained as now with four less men.

Car Tracks: The amount of car tracks affects the cost of cleaning because of the extra time required to sweep the dirt from between the rails, and the interference of the rails with continuous cleaning. This difficulty is responsible for the employment of two sweepers.

To sum up these elements of difficulty which affect the cost of street cleaning, we find that

Because of the amount of traffic.....	19	men are employed
“ “ character of population	6	“ “ “
“ “ condition of pavements.....	4	“ “ “
“ “ kind of pavement	4	“ “ “
“ “ amount of car track	2	“ “ “
Total	35	“

This means that of the forty-two men now employed in sweeping the streets in the bureau's territory, thirty-five are necessary because of the unusual conditions presented in the factors named above. In other words, if our street area were in a residential section of the city, for instance, where the pavements are smooth and in good condition, where the traffic is light, and but little refuse finds its way into the street, and where there are no car tracks, it could be kept clean with seven men.

The bureau flushes nightly, except Sunday, all the streets within its jurisdiction. For this purpose two flushing machines, provided with pumps, operated by gasoline engines, are employed. It is found that the pressure at the hydrants is not sufficient to give a thorough washing effect, so the auxiliary power is necessary. The object of the flushing is to remove from the street pavements the fine dust which the push brooms cannot gather up. In other words, it in no sense takes the place of the hand cleaning, but simply supplements it.

The sprinkling of the streets was taken up by the bureau the past spring, and will hereafter be a part of its work.

On days when any wind is stirring, it will be noted that some street refuse, principally papers, is blown from the street to the sidewalks and often from the sidewalks back into the street again, but much of this remains on the sidewalks, except where almost constant attention is given them by the tenant. To remedy this condition as far as possible, the bureau employs men who cover all of the sidewalks from three to four times a day.

Another activity recently acquired by the bureau, is the removal of cinders and rubbish from the downtown stores and office buildings, numbering at present 160. Two-horse wagons of 6

cubic yards capacity are employed in this work. The cinders are disposed of by sale to builders and others when there is a market, and at other times are given away. At certain times in the winter it is even necessary to pay for their disposal.

The removal of snow from the streets in the district covered by the bureau's forces is also handled by the latter. In the event of a snow-fall, the regular men begin to sweep the snow into piles along the curb where it is out of the way of traffic. If the fall of snow promises to be heavy, extra men are employed to assist the regular men. In the meantime the team owners have been notified and as quickly as teams report, the work of removal starts and is continued uninterruptedly, day and night, until the streets are clear. The promptness with which the snow is removed is dependent on the number of available teams. The temporary character of the work, which is also confined to the small area covered, is not a sufficient inducement for a team owner to make special arrangements for it, so dependence can be placed only on the number of teams that happen to be idle at the time.

The uncertainty as to the time of the arrival of the snow, the depth of fall, the accompanying temperatures, and the number of teams available make snow removal a transportation problem very much out of the ordinary. The teams are paid by the cubic yard of snow hauled, rather than by the day, as an incentive to each team to make as many loads a day as possible, and so hasten the work.

When a wagon reports on the work, it is measured and its yardage computed and entered on a blank form, together with the names of the owner and driver. As soon as the wagon is loaded the driver reports to the foreman, who inspects the load, notes the number of yards, punches this number in the margin of a ticket printed especially for the purpose, and after recording on his report opposite the driver's name, the number of the ticket, presents the ticket to the driver as a tally of the indebtedness of the bureau for so much snow. Each foreman has tickets of a distinct color and series. The punch marks of the various foremen also differ, so that in cases of dispute, lost or stolen tickets, attempts to change the face of the ticket, or any dishonest work, the ticket involved can be traced through the owner, driver, and foreman to the day or night and approximately to the hour when it was issued.

The extra laborers required during snow removal are given a ticket each day, and as a check on their time these tickets are punched at intervals during the day. The implements which the extra men take from headquarters are also noted on the ticket and are checked up at night, the holder of the ticket being responsible for any tool he fails to return.

The entire cost of the work of street cleaning for the past five years has averaged \$58,758 per year, and the cost of snow removal has averaged \$11,886, or a total of approximately \$70,000 per year.

On this amount the city paid \$36,000, the street railway companies approximately \$12,000, and the tenants and property owners the balance, or \$22,000.

DISCUSSION.

Eugene A. Rummeler, M. W. S. E.: In the neighborhood of the Northwestern station there is a great deal of dust. It does not seem to be taken care of at night, and in the morning, just about the time we are coming from our trains, the street is full of men; often it is windy, the wind blowing crosswise. Much of the dust raised by the sweepers is carried away by the passers-by, I presume. The same is true of the sweeping of the sidewalks. It is generally dry sweeping by the occupants of the buildings. The dust is simply raised in the air, then blows somewhere else, and has to be handled over and over again. It seems to me there ought to be some solution of the problem, some way of getting rid of that finely divided material. I would like to know whether it is feasible to stop entirely this dry sweeping.

Mr. Fox: The difficulty in most cities is that the sprinkling is left to the property owners. There are a few cities,—for instance, Boston, Detroit, Indianapolis,—that sprinkle their streets. In New York City we used to have much difficulty on account of the dust. We could not get the contractor to sprinkle early in the morning just before the street cleaning began. We had trouble in Chicago for the same reason, and not until we began to do our own sprinkling were we able to handle the dust nuisance. I think we have now done away with it quite completely. But the only solution of the problem seems to be for the city to control the sprinkling and handle it in conjunction with the street cleaning in such a way that light sprinkling will be done before the cleaning. Another trouble with the private contractor, according to our experience in New York, was he did not sprinkle the street, he deluged it, making the sweeping much more difficult.

Mr. Rummeler: Is it feasible to use, in a city like Chicago, a flushing system with hose attached to hydrants, such as is used in Detroit?

Mr. Fox: The trouble with hose flushing, depending on the water pressure at the hydrant, is that the pressure in Chicago (downtown) is not sufficient. I do not know how it is outside of the downtown district. We used the hose here every summer for four or five years, until two years ago. We got a certain amount of water on the street and it was washed after a fashion, but not very effectively. It is, however, better than no flushing. The bureau used for a season two so-called gravity flushers which depended on the pressure in the water cart for their effectiveness. The first part of the load was discharged with considerable washing effect, but the pressure diminished rapidly and the last half of the water in the tank ran out under gravity.

For the past two years we have used flushing machines pro-

vided with air pumps operated by gasoline engines, which enables us to discharge a tank down to the last gallon and under a uniform air pressure. The object of the flushing is to remove from the streets the fine dust which the push brooms cannot gather up. In other words, it in no sense takes place of hand cleaning, but simply supplements it. The difficulty in doing flushing in Chicago on a large scale is that the city has not the necessary funds for the purpose.

New York City has about \$7,000,000 per year for cleaning 1,800 miles of paved streets. (Chicago has about 1,500 miles of paved streets.) The \$7,000,000 includes the collection and disposal of ashes, rubbish, and garbage. For the same service,—that is, cleaning, and removal of ashes and garbage,—Chicago has only about \$3,000,000, and has almost as many miles to clean. Chicago has about the same area as New York, excluding Brooklyn, Staten Island, and Long Island, where the streets are cared for by the Borough government.

Mr. Rummeler: I noticed this morning on Madison Street, in front of the Edelweiss, a pile of dirt that had been standing there for some days. Had that been hauled from the building?

Mr. Fox: Yes; a permit had been issued to leave it there, so we could not disturb it.

Mr. Rummeler: Has the vacuum cleaner system been used with any success in street cleaning? I understand a trial of this system has been made in some European city,—I think it was in Berlin.

Mr. Fox: I do not know of any such system that works successfully. For the last two years the New York street cleaning department has been trying such a machine. It is practically a vacuum cleaner; that is, it is a pick-up machine, and there is some method of controlling the dust inside of it. The trouble with a vacuum machine is that the pavement must be in perfect condition and free from loose bricks or heavy material of that kind. It is unusual for a city to have such conditions. The capacity is limited, too. Another difficulty with this machine in New York was that after being loaded the machine had to be taken to the dump, and considerable time was lost in that way. So the machine is not yet at a point where it is entirely practical.

H. S. Baker, M. W. S. E.: Where are the sweepings and refuse disposed of?

Mr. Fox: Within the last month we have obtained permission to dump them in Grant Park, for filling. Previous to that we hauled them to South Water Street, where we put them on board Illinois Central cars and the railroad company disposed of them at Wildwood. We paid the freight only.

Mr. Baker: That would not amount to as much as disposing of them at the Jackson disposal station, I suppose.

Mr. Fox: We collect and dispose of the refuse for 40c per cubic yard there; that is the whole cost. It would be out of the

question to pay the disposal station charges. The alternative is to haul them out to some of the outlying dumps. Fortunately the city had an arrangement with the Illinois Central R. R. Co. to send the street sweepings from the first ward, part of the eighteenth, and part of the twenty-second over that railroad, and our bureau got in under the same arrangement. I do not know how long it will last. Fortunately, too, the park on the lake front is now open and we are told we will have means of getting rid of the sweepings there for some years. At one time we had to haul them out to Lincoln Park, —a haul of a little over four miles.

Secretary Warder: This matter of newspapers on the streets,—is there any city ordinance prohibiting people throwing papers out on the street? I frequently see on the cars a man reading a paper, and when he is through with it out it goes on the street. A man walking along the street pulls a paper out of his pocket and throws it on the street. Is there not an ordinance against such practice?

Mr. Fox: Yes, the ordinance prohibits throwing anything at all on the street,—even a scrap of paper. If the streets were not very closely looked after, it would be unlikely that we would get the present clean conditions. However, there seems to have been some improvement along that line. I think cleanliness is "catching." I know it is with me. If I walk along a clean street and have a paper in my hand, I hesitate about throwing it down, but if the street is dirty, I conclude that one bit more will not make much difference.

Mr. Warder: I am told that in many of the German cities the police compel a man to pick up a paper, if he has thrown it down, and put it either in his pocket or in the proper receptacle.

Mr. Fox: Yes, that is true of some German cities, and also of Paris. We have the same city ordinance, but it is not enforced.

Ernest McCullough, M. W. S. E.: A friend of mine, living in France, came to the United States to endeavor to introduce an advertising novelty, designed to overcome objections to the littering of streets with handbills. A shoe with a rubber sole bearing raised letters is worn by a man employed to walk the sidewalks. The heel is filled with water which is forced out on the sidewalk, the raised letters printing an advertisement on the wet surface. The advertisement, of course, evaporates in a few minutes, and the police laws are not violated. He could find no market for the invention in America, where the littering of streets with printed matter is generally permitted.

Albert Reichmann, M. W. S. E.: I would ask if ashes and papers are collected by the buildings only. That collection is not included in your fund, I suppose.

Mr. Fox: No, it is a separate account. A good many people—the Building Managers' Association particularly—have, for a number of years, wanted us to remove the ashes from the office buildings, because the previous service had not been very regular and

satisfactory. So we took up the matter a year ago last June. The handling of cinders and rubbish from office buildings, stores, and factories is not a municipal function.

Mr. Reichmann: How is that matter handled in New York? Does the city take care of the ashes?

Mr. Fox: In New York the ashes are handled by private contractors; all ashes from factories or stores or apartment houses are taken care of by the owners. The city does not remove rubbish from any premises but private dwellings.

Mr. Reichmann: That is substantially our ordinance, is it not?

Mr. Fox: No; here the city removes ashes from apartment buildings of less than five apartments.

Mr. Reichmann: Less than five apartments would mean a small building.

Mr. Fox: Some buildings are included which are somewhat larger, I believe. I do not know how strictly the line is drawn. The city removes garbage from all dwellings and from restaurants and boarding houses feeding less than twenty people. If they feed over twenty people, they must collect and dispose of the garbage at their own expense.

Mr. Reichmann: Have you any idea how this money is prorated through the different wards of the city,—this street cleaning money?

Mr. Fox: I understand that this year the efficiency division of the civil service commission, which is making an investigation and survey of the bureau of streets, is going to make its estimate on the basis of the needs of the different wards. Heretofore I think the alderman that had the biggest pull got the most money. As one alderman put it, the man that talks the loudest gets the most money.

Mr. Reichmann: Our ward has 25,000 inhabitants. I believe we get something like \$56,000.

Mr. McCullough: What percentage of the cost goes for hauling and what percentage for cleaning?

Mr. Fox: In 1911, \$728,485.00 was expended by the city in labor on street cleaning, and \$119,494.67 in cartage and sweeping. This does not include removal of garbage and ashes.

W. W. Deberard, m. w. s. e.: Relative to the matter of cleaning sidewalks, I noticed last summer that the city of Denver, or some organization there, is flushing the sidewalks of Sixteenth Street from the hydrants by the use of hose. They drag the hose from hydrant to hydrant the same as a man would use the hose for street flushing. I am wondering whether any other cities are attempting to do that.

Mr. Fox: We are going to do some flushing of the sidewalks this summer, but this last year is the first time we have done anything at all with the sidewalks. So many complaints were received about dirt being blown from the street on to the sidewalk, we decided to sweep them. Just how the flushing of the sidewalks will

be done has not yet been decided. Of course, with hose we have a lot of things in the way,—fire hydrants and various other obstructions. If a flushing machine could be run on the sidewalk as on the street, the work could be done more rapidly. I am afraid it would be a little slow with the hose. It would have to be done in the night after theater hours, because we get complaints about the street being wet, from flushing, around eleven o'clock; but if we do not get to work by eleven we cannot finish by seven o'clock in the morning.

A Member: How do you find this new style of flushing wagon with air compression in the water tank works. They seem to throw out a very good stream of water.

Mr. Fox: It is very effective. The scouring effect is excellent. One can get any pressure, of course, from 10 lb. up to 70, and can even force the water on to the sidewalk.

Mr. Warder: Are those machines expensive? Does the cost include a gas engine, or an oil engine?

Mr. Fox: They cost about \$1,000.00. We have had some trouble with the engines, however. It is hard to get a gasoline engine that will stand the vibration of the wagon. The mechanism is easily bounced out of adjustment. Unless one has a very good man in charge, the engine is out of service part of the time. It ought to be operated by electricity, or, still better, have the machine operated by a motor, with the pump driven from the motor direct. Such a machine will be on the market next year.

Mr. Deberard: I understand the sewer department complains bitterly about flushing the streets, because it fills up the catch basins, and fills up the larger sewers, and causes a great deal of extra labor in cleaning them out. Then, too, the street department complains on account of the flushing carrying away a certain amount of pavement, making the asphalt pavement, particularly, wear out faster than it otherwise would.

Mr. Fox: If a street is thoroughly swept, there is not much dirt left on it, only a very fine dust; but of course there is a good deal of dirt drawn into the sewers during a storm or during the flushing of the streets. I did not state in my paper that every Sunday we clean out about ten catch basins. We average about ten a week, which is good evidence that we appreciate that some of the dirt is washed into the sewers. But we do that much towards adjusting the matter.

I know, of course, that much water does deteriorate an asphalt pavement. I think we do too much sprinkling; the streets are wet too many hours in the day; but if we do not keep them wet we get complaints that there is dust. If I had my way and the pavements were all in good shape, I would flush them only at night. I would not sprinkle them at all during the day, except along the gutters. Most of the dust is next to the curb, and by a light sprinkling there it can be kept down very effectively.

I do not know what effect water has on the creosoted wooden blocks. If they are properly impregnated with the oil, they ought not to absorb much water; but here they have not been down long enough for us to tell much about them.

Herman P. Andresen, M. W. S. E.: I think all members of this Society will appreciate the thorough and able manner in which Mr. Fox has given us facts and figures relating to the important subject of street cleaning. To those who have followed his work since his entry into this city, I think the regret will be that he will not undertake the sweeping of the smoke-laden sky as well.

I am interested in the subject of street flushing. Where a city has paved streets with proper road surfaces and sufficient pressure in the water mains, the method of cleaning by flushing is ideal. It is economical, dustless, sanitary, and eliminates the necessity of street sprinkling. **Water is the best cleanser known.**

The question of the deteriorating effect of street flushing on asphalt pavements was brought up. It seems to me that if the nozzles are properly adjusted, and placed low so that the water will merely skim along the surface with a shovel-like effect, the water will do no harm to a good asphalt pavement. Probably the kind of asphalt used in the pavement has a great deal to do with it. A pure asphalt will not rot. A great many pavements of (alleged) asphalt contain as much as 35% to 45% of mineral and decomposed vegetable matter. Naturally these impurities are the first to wash out where water is continually running, thus causing the so-called rotting of asphalt.

There is another important subject relating to street cleaning, on which I hope the author will enlighten us; namely, the lowly push broom. Engineers who have been in other lines of work for years, but who have suddenly gotten into municipal work, find there is considerable more knowledge required in writing proper specifications or choosing the best broom for their purpose than they had expected. The importance of getting the best wearing broom for the lowest price is realized when one considers that the city of Chicago alone contracts for 1600 dozen per year. Last year the city paid on its large order close to \$8.00 per dozen. In addition, a large number in the aggregate are used in this city by the various park boards, improvement associations, paving contractors, etc. Further information in regard to these brooms would be of interest.

Mr. Fox: I do not know much about the manufacture of push brooms. We put them through a certain test. If they come up to that test, we continue to buy them from that source. A record is kept of each broom that goes out of the shop, the number of the man who has it, and the length of time that it is in use. A record is also kept of whether it is used on asphalt pavement or granite block. Naturally it will last much longer on asphalt pavement. On granite pavement, seven days is the average life of a

broom. On asphalt, the life of a broom runs up as high as twelve or fifteen days. In addition to the broom on the asphalt, a scraper is used, with which most of the work is done, so that a broom is not in use continuously. I believe that a broom made of two rows of African bass with a row of bahia grass on either side, is the most serviceable for our purpose. We have used some of the heavier ones, made entirely of African bass, but the trouble with them is they do not pick up the fine dirt. We must have very fine fibrous material on the outside. Then, too, the men object to using them because they are harder to push, requiring a little more muscle.

W. C. Armstrong, M. W. S. E.: I did not understand very clearly from the paper just what territory is covered by the bureau.

Mr. Fox: The bureau cleans State Street from Congress Street to the river, all streets between State and La Salle from Van Buren to Madison, and all streets between State and Michigan, from Congress to Washington.

Mr. Armstrong: How about Randolph Street?

Mr. Fox: We do not go as far north as Randolph Street. We clean to Washington Street east of State and to Madison Street west of State. The City cleans all streets outside of our territory. Our bureau, in addition to cleaning, flushing and sprinkling the streets, removes the snow and cleans the sidewalks.

From time to time we are asked to extend our territory to include all streets north of Van Buren Street between the river on the west and north and the lake on the east, excepting Jackson Boulevard and Michigan Avenue, but so far it has not been done. The original territory included only the streets between Van Buren Street on the south, Clark Street on the west, Madison Street on the north, and Michigan Avenue on the south. In addition, State Street was cleaned from Madison Street to the river.

Mr. McCullough: Is that any reflection on the city?

Mr. Fox: None whatever.

W. D. Gerber, M. W. S. E.: Does the city handle Jackson Boulevard?

Mr. Fox: No. Jackson Boulevard and Michigan Avenue from Congress Street to Randolph Street are in the South Park System. North of Randolph Street, Michigan Avenue is handled by the city. There is no reflection on the city in any of our work. The fact is, the city cannot afford to spend as much money as we do in our territory. They give us what they would spend if we were not there. We want to maintain our streets at a higher standard than this money would keep the streets, so the citizens contribute enough to do that.

Mr. Armstrong: What method is used on the streets cleaned by the city?

Mr. Fox: The same method is used there,—the block system of hand cleaning.

Mr. Armstrong: Streets like South Water Street are all cleaned at night, are they not?

Mr. Fox: South Water Street, from State to Market Street and the blocks from South Water Street to Lake on La Salle, Clark, and Dearborn Streets are cleaned by a gang of six or eight men, after five o'clock in the evening. They could not get into South Water Street during the day, to do any sweeping.

Mr. Reichmann: I notice from the papers there is a good deal of talk about routing some of the heavy traffic through the alleys. Would that benefit the street cleaning?

Mr. Fox: No; it would not affect the cost, as we also clean the alleys.

C. D. Hill, M. W. S. E.: I am glad to hear that the bureau cleans out the basins. We find a great deal of dirt in them.

Mr. Fox: Do you think that is due to flushing?

Mr. Hill: I do not know whether it is due to flushing or not. The city has not enough money and men to clean out the basins, without reference to flushing. What you do does not matter appreciably.

Mr. Fox: There is this difference, too: on streets that are thoroughly cleaned, of course, and cleaned ten times a day, less dirt is washed into the basins than on a street that is cleaned once a week as in the case of the outlying streets, where a single flushing would wash as much into the sewers as we could get in several days.

Mr. Hill: Some of the catch basins are cleaned only once a year. The only complaint we make of the street cleaners is in connection with outlying districts, where the men brush thick dirt into the basins. It is easier than putting it into a wagon, especially if the wagon is not there. I think the trouble from flushing does not amount to much, but it is the careless use of a broom that is objectionable.

Mr. Fox: I realize that we do wash dirt into the sewers, in flushing, because we keep track of the amount of dirt each sweeper removes. We have measured it very carefully in boxes, and have found that there is less dirt in the summer, when there is flushing, than when there is no flushing, so we must wash some dirt in the sewers. ■ ■ ■

Mr. Rummler: Has Chicago investigated the idea of placing these receptacles for sweepings below the level of the street instead of having them stand on the sidewalk, or is there some reason why that cannot be done here?

Mr. Fox: I am familiar with the efforts being made by the Chicago Association of Commerce. We have plans for a box, but that is as far as we have gone.

Mr. Rummler: There is so much of the sub-sidewalk used, there would no doubt be objection on the part of the property owners.

Mr. Fox: Doubtless there would be objection, but it would be a great convenience.

Mr. Hill: I think there is no objection on the part of the city to placing the box below the sidewalk, but it is difficult to find the space downtown.

Mr. Rummier: Could it not be fitted into the road?

Mr. Hill: No, it requires a cover so that it can be walked on. It is necessary to drain the cavity in which the box is placed. It must be connected with a catch basin so as to drain any water out of it. It is a somewhat difficult proposition. If the sidewalk were being newly built, such an arrangement might possibly be made in front of some building being constructed, if the owner were willing, without much additional expense. But it would be very difficult to put the box in after the sidewalk had been constructed, especially old-fashioned stone slab walks.

Mr. McCullough: The Merchants' Association was organized in San Francisco in 1892 to deal with municipal affairs, and the first work taken up was that of street cleaning. I was connected with the association for several years in the capacity of Consulting Engineer, and therefore had an excellent opportunity to become familiar with the sort of work described here tonight. It was found that the constant patrol system was the best to use and much of the best work accomplished was due to the pioneer work done by Colonel Waring. I made a careful study then, and since, of boxes intended for the storage of street refuse picked up by the street sweepers, and believe that up to the present time no satisfactory box has been produced. A box placed on the sidewalk occupies valuable space. A box placed in a depression under the gutter or under the walk alongside the curb must have a certain amount of play in order to remove it when filled. The space around the box becomes packed with dust and rubbish, which makes it hard to lift out in good weather, while if it becomes wet it will freeze fast in the winter. If no box is used it becomes necessary to have scoops with which to clean the space. Decaying organic matter soon creates a nuisance here as in the case of catch basins. A depression having an opening to the sewer is sometimes tried, but the sewer department complains about the material thus passed to the sewer. It has been proposed, and in some places the attempt has been made, to have circular or octagonal kiosks on street corners, holding cans for refuse. The cans are placed on light trucks and are easily handled, sometimes a small derrick being placed on the ends of wagons for the purpose of lifting the cans. The outside walls of the kiosks are covered with advertisements.

Mr. Fox: We tried sunken boxes in New York when I was in the department. We had a number of them put on Fifth Avenue. They did not work very well, and we did not put in any more of them. This was about the end of Colonel Waring's administration. It was particularly difficult to get them out in the winter time. If

there was any water around them, and it froze, of course it was impossible to get them out; you would have to pour hot water in them or wait till they melted. But the idea in these boxes downtown was to have a connection with the catch basin so that they would drain into it.

Mr. McCullough: In some cities in the United States sewer catch basins are cleaned on an average of four times each year. In other cities they are cleaned on an average once in three or four years. Some are never cleaned. They fill up with the first storm, and after that the street water goes into the sewer, carrying all the detritus, until decaying matter creates an offensive odor. Catch basins are seldom used in Europe. In the United States a number of cities have abandoned them when the sewers have enough fall to carry the waste matter. Personally I am opposed to the use of catch basins, and have held this opinion for over twenty years, because of the excellent opportunities I have enjoyed for studying the subject in many cities both here and abroad.

Mr. Andresen: This question of catch basins has assumed an important part in the discussion, and I beg to ask the author if it is not true that in some instances, where they are using flushers to a large extent, the flushers not only serve the purpose of flushing the streets but the sewers as well, and instead of having more catch basin cleaning there has been less? I think Cleveland possibly has had that experience.

Mr. Fox: I have never had actual charge of any sewer work. My connection with the matter is to try to put as little in the sewers as possible.

Mr. Andresen: I think the suggestion of Mr. McCullough is good. If you run three foot flushers in tandem you could flush it out.

Mr. McCullough: You can do that well in Chicago on account of it being so flat. Wherever it can be done it is a good thing. However, in Chicago I believe catch basins are of no benefit unless you can keep them clean. One storm will fill them up and everything else will go to the sewer. Most of the stuff that is washed off the streets is organic matter anyway. It is not apt to clog. It is only on the old-fashioned pavements where blocks are used that one is likely to get any sand.

Mr. Fox: You want to remember these sewers downtown date back some years. They can be blocked up very easily.

Mr. McCullough: Yes, I know they are pretty well loaded up with grease from the restaurants. That is the principal trouble with the sewers downtown.

AN ECONOMICAL DESIGN FOR A TIMBER COTTON SHED.

E. S. PENNEBAKER, JUN. W. S. E.

Presented November 11, 1912.

Before the Bridge and Structural Section.

INTRODUCTION.

The Mobile & Ohio Railroad Company has recently erected a large cotton storage shed on its docks at Mobile, Alabama, to provide storage space for the protection of cargoes of export cotton from damage by bad weather during the heavy shipping season. Prior to the completion of this improvement, it was often necessary to hold many thousand bales of cotton on the docks, partially protected by tarpaulins, or in cars under per diem charges, for days at a time awaiting the arrival of the big freight steamers that carry this cotton to foreign markets. This method has always been a very expensive one, especially at the height of the shipping season, when cars loaded with cotton have congested the terminal yards and cut down the supply of empties needed to handle the crop from the interior to the port for compress and export. In addition, claims were often filed against the company for damage to cotton, on account of alleged poor facilities for protection from wet weather.

Taking as a basis the figure given by the foreign freight department of the railroad company as the average cost of protecting cotton with tarpaulins, that is, 1c per bale per day, the wisdom of this investment was most forcibly demonstrated during the past record-breaking cotton season. In the month of December, when the big crop in the Mobile & Ohio Railroad, and Southern Railway territory seemed to concentrate on the Mobile docks for foreign shipment, there occurred an unprecedented rainfall of 10.02 in., of which 4.51 in. fell in two consecutive days. Rain was recorded on thirteen days of this month. The expense of protecting with tarpaulins and in cars, from such weather, the daily average of 5,000 to 8,000 bales stored on the Mobile & Ohio Cotton Pier alone, exclusive of the 7,500 bales crowded under the new shed, would have paid splendid interest on an additional investment two or three times as great.

GENERAL DESCRIPTION.

The new cotton shed is a timber structure covering a smooth concrete floor. It is 135 ft. in width and 410 ft. in length, fronting the dredged channel of the Mobile River. The building was erected and thoroughly equipped by labor contract, the railroad company furnishing all materials used in construction. The work

was done under the supervision of the construction department and completed in approximately 60 working days at a cost of 22.2c per sq. ft. of floor area, exclusive of fire line and lighting, or at a total cost of 27.5c per sq. ft. of floor area. This structure covers a floor area of nearly 1 1/3 acres, has a capacity of 7,000 bales of compress cotton piled single tier, is provided with ample fire protection, is electric-lighted with Tungsten lamps, and is served with well-arranged track facilities which reduce to a minimum the cost of shipside delivery as stipulated in the contracts with the various steamship lines loading at the Mobile docks.

The location of this shed on Pier No. 2, and the layout of the various tracks serving docks and terminal facilities along the water front in that vicinity, is shown in Fig. 1.

DESIGN OF SUPERSTRUCTURE.

There are some unique features incorporated into the design of this timber structure, which, from a practical railway engineering and architectural standpoint, may prove of interest to the members of the Society. These features were adopted by the company's architect with a view of securing the maximum usable value of the money invested,—in other words, with the idea of securing an efficient design with a minimum of waste space and waste material. The comparatively low construction cost of this shed, and the satisfactory all-around service realized from its use during the past season, has seemed to indicate that the type of construction adopted has accomplished the desired results.

As will be seen from the illustrations, the butterfly type of roof has here been utilized to advantage, thus permitting the employment of low-pitch, shallow-truss construction, effecting maximum economy in roof-framing, sheathing, and roof-covering, and affording ample clearance for cars on the tracks paralleling the building on either side. In addition, the high eaves afford excellent light along the outside bays, and provide much better light throughout the interior bays than is ordinarily secured in buildings of similar width and height, with few skylights. The employment of this type of roof also obviates the necessity of any guttering whatsoever, the roof drainage being taken care of through downspouts in the valleys and sub-drainage to the river.

A roof loading of 30 lb. per sq. ft., or about 20 lb. per sq. ft. less than the ordinary recommended practice for structures of this type, was assumed in the design of this shed. This 20 lb. per sq. ft. deficiency represents the snow and sleet load to which buildings farther north are subjected in the winter season. This snow load can safely be eliminated along the Gulf Coast, and the design economized to that extent. The various items

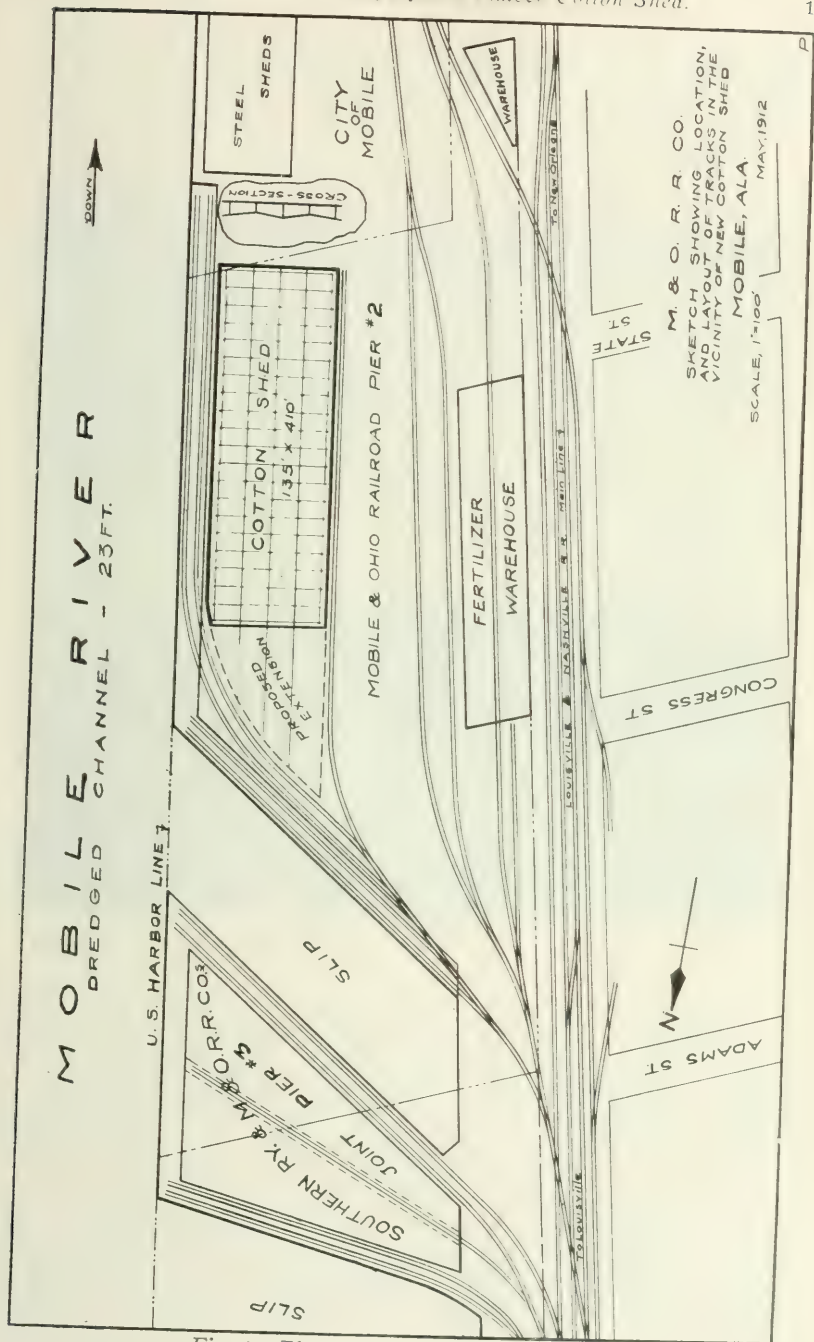


Fig. 1. Plat of Property and Tracks.

which combine to make up this loading, together with the weights of each per square foot, are listed below:

Material.	Weight per Sq. Ft.
Sheathing, $\frac{7}{8}$ in. by 6 in. T. & G., L. L., Y. P.....	4.00 lb.
Composition roof—felt, asphalt, gravel.....	10.00 lb.
Wind load—40 lb. per sq. ft. on 1/25 pitch.....	1.60 lb.
Dead load—rafters, purlins, rods, etc.	6.00 lb.
Excessive rain, downspouts clogged, at.....	8.40 lb.
Total	30.00 lb.



Fig. 2. New Cotton Shed, Wharf Front and Tracks, Mobile River.

Roof-trusses: The roof is carried on shallow trusses, or trussed beams of built-up section bolted together. These trussed beams have a span, center to center of columns, of 30 ft. each, and are tied together the full width of the building in series of four trusses each. These series-trusses are spaced 20 ft. on centers, this arrangement of column spacing giving a $7\frac{1}{2}$ ft. overhang of the eaves on the sides of the shed, and a 5 ft. overhang at each end.

In order to eliminate waste ceiling height and reduce the height of columns to an economical minimum, the 4 by 12-in. purlins, in addition to performing their primary function, act as struts for the trussed-beams. It will be noted that the main compression members of this truss consist of four pieces of 2 by

6-in material, bolted together through the columns and through fillers over the purlins. One of these 2 by 6-in pieces is a rafter moved a few inches from the regular spacing and bolted to the beam to insure additional strength. The use of a beam of this type and of the same depth as the rafters, was primarily neces-



Fig. 3. Interior View of Shed, Looking Toward Commerce Street.

sary as a detail of the type of construction adopted. It also accomplished economy in material and facilitated erection. In addition, it aided in securing the prompt delivery of material for the building, the 2 by 6 timbers being stock size, readily available at practically all mills for quick delivery, and at a reasonable price. As orders were not placed for the material for this shed until the last week in August, only 30 days prior to the opening of the cotton shipping season, quick delivery of material, especially the lumber, was a most important requirement.

All timber used in the structure is long-leaf yellow pine, selected under the Square Edge and Sound specifications of the Yellow Pine Manufacturers' Association. The columns, purlins, and girders were specified to be 80% heart stock.

The tension in the trussed-beams is carried by 1½-in. round steel rods, which support the purlins on cast-iron bearing knees, and are connected with clevis-nuts and cotters at the ends to ⅝-in. steel plates, which are supported by the 2 by 12-in. longitudinal girders. Turnbuckles in the center of each span afford a means of adjusting the tension in the rods after the

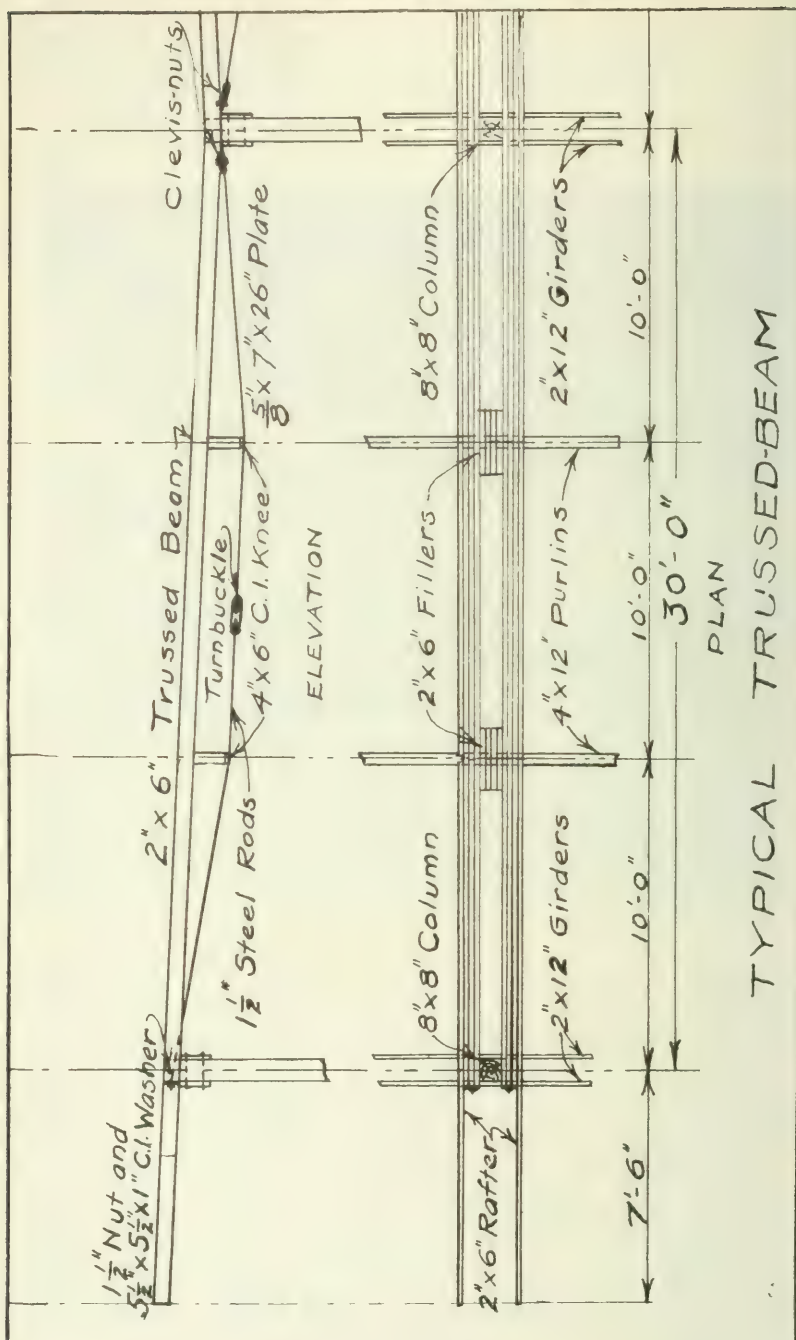
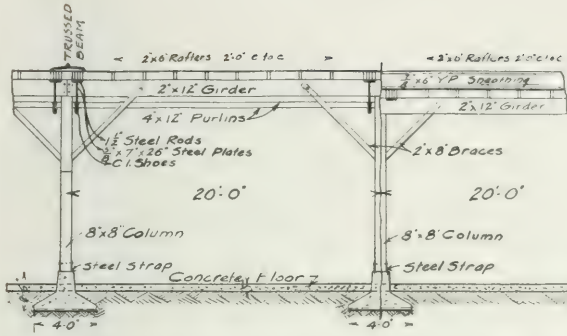


Fig. 4. Roof Truss.



LONGITUDINAL-SECTION $\frac{1}{4}" = 1'$

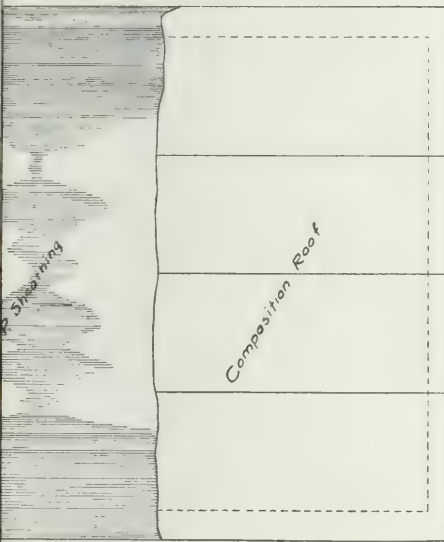
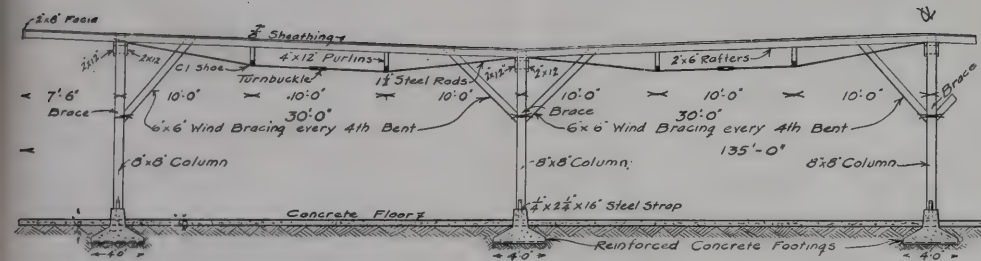
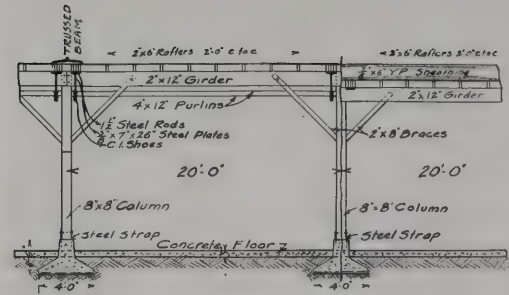


PLATE I

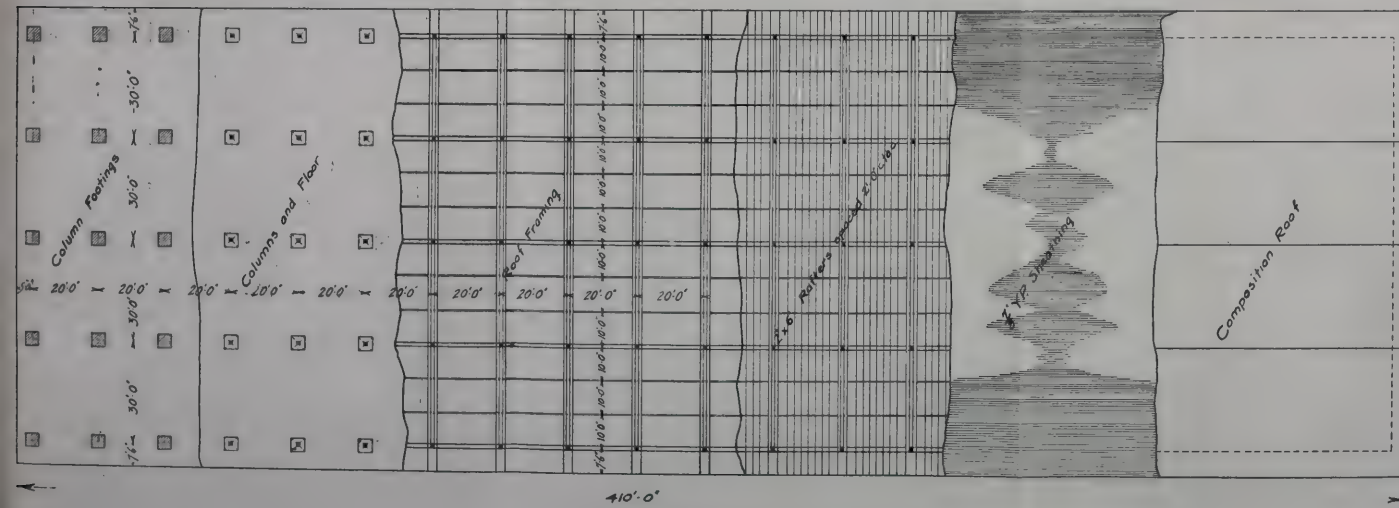
M. & O. R. R.
COTTON SHED, PIER 2
MOBILE, ALA.



CROSS-SECTION $\frac{1}{4}'' = 1'$



LONGITUDINAL-SECTION $\frac{1}{4}'' = 1'$



PLAN

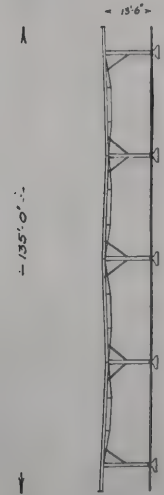


PLATE I

roof is swung. The four spans in the series-truss are securely tied together and fastened at the ends of the outside bays by a combination of a square nut and heavy cast washer, where the rods pierce the outside longitudinal girder.

The depth of the truss, center of beam to center of tension rod, is 19 in. The 4 by 12-in. purlins with the 2 by 12-in. girders are spaced 10 ft. on centers. The column spacing of 20 ft. longitudinally was adopted largely because the limiting length of the purlin and girder designed for a roof loading of 30 lb. per sq. ft. is approximately 20 ft. The rafters were arbitrarily spaced at 2-ft. centers.

Columns: The columns are 8-in. by 8-in. timbers, dressed four sides. Theoretically, a much smaller column would safely support the load, but owing to the liability to injury or displacement by heavy trucks or by drays when unloading cotton under the shed, it was thought best to adopt the 8-in. by 8-in. column. The average man's practical sense of right or proportionate sizes for the various component parts of a simple structure of this kind, had some influence here, also.

Longitudinal 2-in. by 8-in. bracing is provided at every column, bolt-connected both through the columns and through the two girders. Wind bracing of 6-in. by 6-in. timbers is provided for at every fourth series-truss, as shown in cross-section on Plate I. This is also clearly indicated in one of the illustrations looking down one of the middle bays, the full length of the building. Eave-ties of 2-in. by 8-in. timbers have been placed at each of the outside columns on either side, the full length of the building.

Stresses: In proportioning sizes for the timber truss members,—purlins, girders and columns, and the rods used in tension,—the following safe unit stresses, adopted as standard by the Mobile & Ohio Railroad Company for building construction, were used:

TIMBER.

In Tension: 2,325 lb. per sq. in., deflection not considered. This is based on a bending strength at rupture of 7,750 lb., and a factor of safety of 3 1/3. Material air dry assumed at 18% moisture.

In Compression: 1,500 lb. per sq. in., using the following column formula:

$$f = \frac{1500}{1 + \frac{l^2}{700 + 15 \frac{l}{d}}} \left(\frac{l}{d} \right)^2$$

where f = Allowable working stress for long columns.

l = Length in inches.

d = Least cross-sectional dimension in inches.

STEEL RODS.

16,000 lb. per sq. in. of net area.

Column Footings: The column footings are constructed of slag concrete, mixed in proportions of 1:2½:5. They are designed for a safe crushing strength of concrete masonry assumed at 8 tons per sq. ft., and an allowable foundation pressure of slightly over ½ ton per sq. ft. As a precautionary measure, due to the character of the foundation, which is largely pumped-in river sand over clay and sand, and confined within timber bulkheads, the bases of these footings, which are 4 ft. square, were reinforced with ¾-in. steel rods arranged in two laminations at right angles to each other, the rods in each spaced 6 in. center to center.

Floor: The concrete floor under this shed has proved to be a most economical and serviceable part of the structure from the standpoint of trucking cotton from shed and pier to shipside, and will no doubt soon prove its economy from a maintenance standpoint. This floor consists of a 4-in. slab of slag concrete mixed in the proportions of 1:3:6, with a 1-in. top of cement mortar, smoothly finished. The slab is cut into sections 10 ft. square to prevent cracking, and sufficient asphalt expansion joints are incorporated for safety. So far, the floor has stood up in fine shape under very heavy trucking.

Downspouts and Sub-Drainage: Galvanized iron downspouts, with roof-entrances capped with wire screens, are spaced at intervals of 40 ft. along the two valleys of the shed. These downspouts are securely fastened to the columns with wrought-iron straps, and convey the roof drainage to the vitrified tile sub-drains. These tile drains are laid about 2 ft. below the concrete floor and carry the water through the bulkhead into the river.

Fire-Protection: The requirements of the Fire Underwriters for the protection of cotton storage warehouses are unusually rigid and strict, due to the inflammable nature of the staple. The cost of fire protection is, therefore, quite an item in a timber shed of this type. The building is equipped with a 4-in. fire line, supplied from the city mains, and tapped by six plugs. Each fire plug is equipped with the required number of feet of regulation hose supported on swinging bracket reels of recommended design. In addition, the Underwriters have required the maintenance of 100 galvanized-iron fire buckets, which are now suspended from the columns of the building for emergency use. One or two ships have been discovered on fire recently, while loading cotton at this pier, and the fire line has rendered excellent service in extinguishing the blaze.

Lighting: During the busy shipping season, it is necessary for the big freight steamers to work night and day taking on cargo, and for this reason a lighting system was required in this

shed. This feature is taken care of by an efficient and well-designed system of Tungsten lamps with Hubble effusive type reflectors. A 100-watt Tungsten light is suspended in the center of each one of the 84 bays, and the results obtained are most satisfactory. Current is supplied by the city electric plant. Arcs are used along the pier fronting the shed.

Construction Costs: Detailed cost data were secured in connection with the construction of this shed, and below are given a few of the unit costs covering material in place in the building, which may be of interest as indicative of gulf coast costs for work of this character. All common labor used was negro labor. The figures given do not include freight:

Reinforced concrete column footings, \$3.93 per cu. yd.

Concrete floor, slag concrete, \$0.6296 per sq. yd.

Lumber in place in superstructure, \$20.73 per M. ft. B.M.

Steel rods, plates, etc., in place, 4.61c per lb.

DISCUSSION.

F. E. Davidson, M. W. S. E. (Chairman): The thought occurred to me, in connection with this paper and the daily problems engineers have to contend with, that there has been quite a change in the relationship of the architect or the engineer to industrial problems from the practice of years ago. Take all the monumental architectural landmarks in Europe, or anywhere in the world. A man would devote his lifetime to the construction of one building; often more than one man would devote a lifetime to one structure. Even fifty years ago an architect or an engineer who would handle, say, a quarter of a million dollars worth of business per year was considered to have an enormous practice. But today, if a firm is not handling about that much work per month, it does not stay in business very long. The demands of commerce and of clients are such that the modern engineer and architect who are in business either in an active or consulting way have to have as employees skilled experts in almost every line. They have to specialize. The really successful engineer or architect is more of a business man than the designer; his time is taken up with the business end of the organization, the administration features, and all that he can do for his client is to outline the problem in a very broad, general way. He can give little time even to checking designs. The demand of the client, the demand of the business, is such that he cannot do anything else. In my own experience, when employed by a large corporation, I remember being called to the office of the General Manager at one time, who said: "Mr. Davidson, I promised our Board of Directors that we would erect a certain building and have it ready for occupancy in sixty days." It had not even been designed. It was to be fireproof construction and cover about 75,000 sq. ft. of floor. To handle work that way simply means that a member of the firm must devote his time to the business end rather than to the technical design.

A client will come to you and give you a commission to design a building, and then ask, "When can I have this?" He will probably give you two or three weeks to make a complete design, write specifications, and take bids on a fireproof building. Those who are in the profession know that these are conditions we have to encounter, and in order to keep in business we have to complete our organization to meet that kind of competition. If we do not, the man with organization is going to get the business. So today a man has to handle more business in a month than our professional brother did in a year fifty years ago, in order, perhaps, to make the same amount of profit he did. Our expenses are greater.

Mr. Pennebaker: Mr. Davidson's description of what the modern engineer is "up against" is certainly correct. Those who have had any experience with railroads in these days when the railroad commissions are so closely behind them, realize that the engineer is "up against it" there, as much as, if not more than, those who are in private work.

Referring to the heading "General Description," second page of the paper, I will say that the Mobile & Ohio Railroad Company has recently purchased two slat conveyors for service at the Mobile docks. These will permit increasing the capacity of the warehouse to about 14,000 bales, by piling cotton double tier.

Under the heading "Design of Superstructure," the last item of the table of material—"excessive rain, downspouts clogged, at 8.40 lb."—was included to make up the 30 lb. There is a chance for the valleys to become clogged, so there might be at some time six or eight inches of water, which will figure quite a material load.

The formula under the head of "Timber" is a modification of the Gordon formula, and the constant was determined from a test of 50 long-leaf, yellow-pine columns that was made on the M. & O. R. R. several years ago. This constant was developed from those tests, and has proven very satisfactory. The quantity "f" in this formula is the allowable working stress in pounds per square inch, for long columns.

Mr. Davidson: What rate of insurance was given by the Underwriters' Association on this plant, and what would the rate have been if a complete automatic sprinkler system had been installed?

Mr. Pennebaker: I have forgotten the exact rate on this shed, but it was quite high,—\$1.50 per hundred, I think. The rate on a steel shed which the city built shortly afterward was practically the same; the same form of protection facilities were installed. As to the difference in the rate, provided a sprinkler system had been installed, I am not prepared to answer that question.

In regard to the fires which occurred down there. The M. & O. R. R. Co. has a 25-ft. wharf in front of this shed; a fire was discovered in the hold of a ship, and they were able to put three lines

of hose into the hold. The fire-fighting facilities are, therefore, quite efficient.

Since the writing of my paper, the M. & O. R. R. Co. has built an extension of 200 ft. to this cotton shed, as shown on Plate I, which gives an additional storage space of 2,000 bales.

H. S. Baker, M. W. S. E.: How is the cotton handled in and out of the shed? Is it all trucked by hand?

Mr. Pennebaker: The cotton is handled in cars and by drays. A great deal of it comes from steamboats, and this is hauled by the one-mule drays (so common in the gulf coast cities) and stored in the shed or under tarpaulins until such time as the ships come. During the heavy shipping season, the Mobile river front is filled with cotton, and for four or five blocks back from the river bales of cotton are many times piled along the curb. It is loaded on to the ships by the old-fashioned method,—ship derrick and cables that swing two or three bales at a time; a slow method. The railroad company is now figuring on the unit system of conveying. This comprises an adjustable slat conveyor, which picks up a bale of cotton and elevates it to the deck. The conveyor can be set at any angle up to about 60 deg. In this way the cotton is taken from the shed, hoisted to the ship's deck, and shot into the hold.

J. H. Warder, Secretary: When the drays come from some other point about town, bringing in the small lots of cotton, do they drive right across the tracks that are alongside the shed, at any point that may be convenient, and under the shed to unload?

Mr. Pennebaker: We usually have the drivers unload at the end of the shed, and then truck the cotton into the shed. We do not let the drays go on the concrete any more than we can help. Those who have had experience with the average negro drayman and a one-mule dray are aware that it would be unwise to let them go under a shed of this kind. The truck used is the ordinary low two-wheeled, freight-house truck. Quite a force of truck men is required to handle the cotton in and out. During the cotton season it is one of the busiest places in the country. Cotton is loaded night and day.

The bales go to different firms in Liverpool, and each batch bears a certain mark. A rope is put around each firm's loading, and it is stored in one particular part of the ship. Many times one would almost need to be a Philadelphia lawyer to determine what is meant by those marks.

Ernest McCullough, M. W. S. E.: The next development will probably be a somewhat heavier construction of shed, in which can be placed some form of telferage system to handle freight instead of by means of trucks.

Mr. Pennebaker: Almost every gulf city is counting a good deal on the Panama Canal.

It was figured, when this shed was proposed, that the water frontage of Mobile is increasing in value so rapidly that the wise

thing to do would be to erect a temporary structure. It had to be put up quickly, so timber construction was decided upon, with the idea in view, I understand, of substituting, at some future time, a concrete structure with, say, a double or triple deck, if the demands for this storage space then made that necessary. In that way, all cotton-handling facilities will be concentrated in one place for ship-side delivery. This, it seems to me, is a very good idea in a railroad export yard.

Mr. Davidson: Who pays the insurance on the cotton, the railroad company or the owner?

Mr. Pennebaker: The owner.

Mr. Warder: How high is that concrete floor above the average level of the water in the bay?

Mr. Pennebaker: It is about 4 ft.

Mr. Warder: Then you have a very free outflow without special draining?

Mr. Pennebaker: Yes, we have very good drainage.

Mr. Warder: Is there much tide?

Mr. Pennebaker: I have seen the tide as much as 2 ft., but that is what we would call extra. When there is a strong south wind, the tide has been known to go as high as 4 ft. to 6 ft.

Mr. Davidson: Have you ever made any estimate of the cost of an absolutely fireproof storage shed equipped with a complete modern automatic sprinkler system, and have you ever secured any rating on such a structure?

Mr. Pennebaker: Our insurance agent estimated that there would be a saving of about 25 per cent on such a structure over the present one. He said there was practically no difference in the rate between our timber structure and the steel shed recently erected by the city of Mobile. That is unprotected steel.

Mr. Davidson: In designing the roof truss, what bearing did you figure on for compression value for the timber across the grain? The reason I ask this question is, I note from the details there is no bearing plate on top of the posts.

Mr. Pennebaker: You will note that those trusses are bolted through the posts; you understand that, of course; *i. e.*, the beam is made up of 2 by 6 stuff, built up to 6 by 8 section, and that is bolted through the top of the column.

Mr. Davidson: Then you figure the bearing plate in transmitting the load rather than the compression across the grain?

Mr. Pennebaker: Yes. There was quite a problem in swinging that roof. The steel plates over each girder straddle the posts. The plate does not show very clearly. There is a rod connected to each end of each plate, that is located right under the center line of each beam—that is, the plate rests on the girder itself. (The arrangement can be seen in the side elevation of the sketch.) It is necessary to work the four sections or series trusses at once. There is a heavy cast washer alongside the outside column. All

the slack was taken up in turnbuckles. After the first two or three bents were put in, however, it was easy work.

J. T. Brown: The author mentions slag concrete. What kind of slag concrete is it? Where is it secured?

Mr. Pennebaker: It was a blast furnace slag and was secured at the plant of the Woodward Iron Company, Birmingham, Alabama. We also secured some at Holt, Alabama.

Mr. Davidson: What is the approximate selling price of a bale of cotton?

Mr. Pennebaker: A bale of cotton weighs 500 lb., and it is worth all the way from 6c to 12c per lb. Just at present it is worth about 11c. Compressed cotton weighs about 15 lb. per cu. ft. I have been told that it takes 1,700 lb. of raw cotton to make a bale. 1,100 lb. of that is seed, 500 lb. is cotton fiber, and 200 lb. is dirt. I have had occasion to check that two or three times, and it is quite close figuring.

This is my first experience with slag concrete. It makes an exceedingly fine looking piece of work, and is very easily handled. It is the most inexpensive aggregate that I have ever seen used.

Mr. Brown: Was it crushed slag, or right out of the pit?

Mr. Pennebaker: I understand that it was right out of the pit. Of course, it was broken up to about the size desired.

Mr. Warder: What is the haul on that slag?

Mr. Pennebaker: The haul is about 200 miles.

Mr. McCullough: Were any tests made on the concrete?

Mr. Pennebaker: We tested the neat cement, but not the mixture. On the extension the cost per square yard of floor area was cut to 52 cents, as a result of better organization and previous experience.

A Member: For instance, \$3.93 for reinforced concrete column footings.

Mr. Pennebaker: That was handled very economically. There is a very large item in cement, you know. That cement was purchased at a very low figure, much lower than the average cost of cement in that country.

Mr. McCullough: In regard to the reinforced concrete column footings, does the \$3.93 per cu. yd. include the cost of the slag laid down on the job?

Mr. Pennebaker: Yes, exclusive of freight.

Mr. McCullough: How much would the freight add to that cost?

Mr. Pennebaker: The freight on coal from Birmingham to Mobile is \$1.10 per ton. Slag should be cheaper, about \$1.00 per ton, or I might say \$1.00 per yard. That would bring the cost of the footings, including freight, very close to \$5.00 per cu. yd.

Mr. McCullough: In regard to the slag concrete floor, it costs about 7c per sq. ft., but the freight must be added, I suppose.

Mr. Pennebaker: Yes, the freight would have to be added, but

it would not amount to much on a square foot of slag 4 in. thick— $1/3$ cu. ft.

Mr. McCullough: The weight of the slag concrete will run about 138 lb. per cu. ft. One-third of that you will see runs up the price, if you add freight.

Mr. Pennebaker: A third of a cubic foot of slag would not weigh over 30 to 40 lb.; 30 or 40 lb. in freight at \$1.10 per ton is a small item.

Mr. McCullough: Did you use sand, or take the slag as it would run?

Mr. Pennebaker: We used sand available on the job.

Mr. Davidson: I cannot figure, to my own satisfaction, that this is the most economical building for a cotton shed. Fourteen thousand bales of cotton at the present price of cotton will give approximately an insurable value of \$750,000. Then, at the insurance rate of \$1.50 per hundred, the insurance charges on the contents alone will be approximately \$11,000 per year. That amount will pay maintenance charges on a good reinforced concrete building with a complete automatic fire sprinkler equipment. I think a great saving in the insurance rating might be effected by the installation of an automatic sprinkler system. In the New England cotton mills, where there are thousands of dollars' worth of cotton in bales stored in modern reinforced concrete buildings, completely protected with automatic sprinkler systems, the insurance rating is only $4\frac{1}{2}c$ instead of \$1.50. I venture the assertion that if the railroad companies were paying the insurance charges they would build better sheds.

Mr. Pennebaker: The railroad companies are paying insurance charges on the sheds, but not on the cotton.

Mr. McCullough: Your standpoint was this: The shed was built by the railway company; they simply pay insurance on the shed, and the insurance on the cotton is paid by the owners, who heretofore made the railway company supply the tarpaulins, and in case of damage made the railway company pay the damage.

Mr. Pennebaker: Yes, that is correct.

Mr. McCullough: The only remedy would be for a warehouse company to take over the whole proposition.

Mr. Pennebaker: There would have to be a third party to take care of that.

Mr. Davidson: The insurance body which controls insurance rates is located here in Chicago. In fact, there is a governing board located here which controls the insurance rating from Pittsburg in the east, and from the Gulf of Mexico to the Canadian line. That board will not give any better rating on an unprotected steel building than it will on a wooden building, but if the steel is protected that is an entirely different matter.

Mr. Pennebaker: The city of Mobile has put in a shed 138 ft. long by 120 ft. wide, at a cost of something like \$70,000.

This is of the construction mentioned, simply an open steel structure; and there is no better insurance rate on that than on the railway company's timber shed. There is a great deal of waste ceiling there that is of no use whatsoever.

I learned quite a good deal about the Underwriters in that locality. We had an inspector on the job there, it seemed to me, about every six or eight days during the cotton season. After the shed had been erected, there was quite a controversy growing out of an order issued requiring about four fire buckets to be hung on every post. The company's insurance agent finally reduced the number of buckets to 100, in addition to the fire line. I think if it had been possible, the Underwriters would have had the entire shed enclosed with water all around—a sure protection.

Mr. Davidson: If the railroad company had been paying the insurance it would have had a water curtain, I am sure of that. There is a value of almost \$1,000,000 on the cotton in that shed.

Mr. Pennebaker: We are not paying insurance on the cotton at all.

Mr. Davidson: The shipper of cotton has to take his cotton there and pay the insurance, or let the cotton rot.

N. M. Stineman, JUN. W. S. E.: How many days in the year is that shed filled with cotton?

Mr. Pennebaker: From the middle of September to about the middle of April cotton is stored in the shed. After that there is often a great deal of sisal stored there. The shed is in service practically all the year.

Mr. Stineman: Does the insurance on the cotton cover the whole year?

Mr. Pennebaker: No, it covers about six months.

I looked at some new docks in New Orleans last April. They are nearly all of concrete construction,—very fine structures. But, unless you have a very good designer and a good inspector on the job, there is liable to be a slump or two, and there are eight or ten columns down there which are not even supporting their own weight or any part of the roof. There are fifteen or twenty angle irons tied into various parts of the shed, in an attempt to hold these columns in an upright position.

Mr. Stineman: Do the docks require a much higher rate of insurance than the cotton stored in the cotton mills, from the fact that there are so many darkey laborers in that shed during the rush season?

Mr. Pennebaker: No smoking is allowed anywhere on the docks. The rules are very rigid on that. The greatest danger is sparks from passing steamboats or engines, I should say.

In regard to the handling of cotton, I understand that at South Memphis, Tenn., is one of the finest cotton warehouses in the country. It is said to be the finest in the world. The telpherage system is

employed. In passing by, I saw a pretty well broken down mule hauling what looked to me like a hundred bales of cotton, hung up on the telpher. The capacity in that warehouse is about 1,000,000 bales. The construction is of concrete and steel. They own all their tracks and an immense acreage of ground. This year they are adding about one-quarter to the capacity of the plant.

IN MEMORIAM

CHARLES LEWIS HARRISON, M. W. S. E.

Died September 14, 1912.

Charles Lewis Harrison was born at Aux Vasse, Calloway County, Missouri, on his father's farm, March 5, 1857. His parents were Thomas Harrison and Catherine Maddox Harrison. The Harrison family were prominent in Virginia from an early day. Charles Harrison attended district school until 1876, when he entered the University of Missouri, graduating in 1880 with the degree of C. E.

From May, 1880, to June, 1882, he was with the Mississippi River Commission on the following duties: As Rodman on discharge measurements at Fulton, Tenn., to August, 1880; as Recorder on same work at Grafton, Illinois, to October, 1881; and as Assistant on hydrographical and topographical surveys at Lake Providence, La., to June, 1882.

He was Transitman on topographical survey of the Missouri River, from Fort Pierre to Fort Randall, Dak., from June to December, 1882; Instrumentman on topographical survey of the Red River of the North from December, 1882, to September, 1883; Assistant on construction of dam across Mississippi River at Pokegama Falls, Minn., from September, 1883 to July, 1884; also making frequent gaugings of the river; Engineer in charge of completion of dam across Mississippi River at Lake Winnebigoishish, Minn., from July to December, 1884.

From 1885 to 1890 he was with his uncle, B. F. Harrison, in the live stock commission business in Chicago.

From July, 1890 to May, 1891, he was Assistant on hydrographic surveys and investigations for the Sanitary District of Chicago; from May, 1891 to February, 1892, Engineer in charge of improvements of the Carp River and building of the sewer system for the city of Ishpeming, Mich.; from February to August, 1892, Assistant Engineer in charge of surveys and location of the Chicago Drainage Canal; from August 1892 to August 1897, Division Engineer in charge of construction of Sections 5 to 15, including the regulating works at Lockport; from August, 1897 to January, 1900, in charge of surveys for a ship canal from Niagara River at Tonawanda to Lake Ontario, and from Troy to Lake Champlain, under the direction of the U. S. Board of Engineers on Deep Waterways; from January, 1900 to June, 1900, he was with the Isthmian Canal Commission, during which time he made surveys of the Panama Canal route for the verification of the work of the French company; from June, 1900, to May, 1902, he was Chief Engineer of the Denver Union Water Company. During this period he designed and built the Lake Chees-

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man dam, notable as sustaining a greater head of water than any other structure then existing, and as being free from leakage of any kind. From June, 1902, to April, 1909, he was Principal Assistant Engineer of the East River Division of the extension of the Pennsylvania Railroad to New York City and Long Island; from April, 1909, to April, 1910, Deputy Chief Engineer for the Board of Water Supply of the City of New York.

In April, 1908, he suffered an injury of the heart caused by too long a stay in compressed air, from which he never recovered. Although he endeavored to resume regular work in 1909, he was compelled to give up after a year's trial, and from that time limited himself to consultations. He passed the winter of 1910-11 in California, and the winter of 1911-12 in Havana, where he became greatly interested in the raising of the "Maine" then in progress. In March, 1912, he visited the Panama Canal.

In the latter part of August, 1912, he contracted a slight cold, which did not take a serious form until two or three days before his death, which occurred September 14th. He was buried in the family burying ground on the old farm in Missouri.

Mr. Harrison became a member of the American Society of Civil Engineers in 1898, and was a frequent contributor to its discussions. In 1904 the Rowland prize for a paper on "The Lake Cheesman Dam and Reservoir" was awarded to him and S. H. Woodard, as joint authors. He was also a member of the University and Engineers' Clubs of New York City.

The foregoing facts, for which we are largely indebted to our fellow member, Mr. Alfred Noble, give us genealogical and other data concerning Charles L. Harrison, but they convey no idea of the man's personality; of those qualities of heart and mind which endeared him to his intimates and won for him and firmly held the esteem and the respect of those who were his subordinates in professional work, or who came in contact with him in business. He was a loyal and helpful Member of this our Western Society of Engineers. Our proceedings contain papers and written discussions contributed by him that have an educative value.

On December 23, 1896, he presented a paper on certain phenomena which were manifested in the rock sections of the Sanitary District of Chicago canal (See Vol. 11, page 25 et sequiter Journal, W. S. E.). In April, 1897, he contributed a discussion on "Deep Wells" (See Vol II, page 209 et sequiter). In November, 1908, he contributed a discussion on "Retaining Walls" (See Vol. III, page 1330), and in the same volume appears (page 1407), his discussion of stadia work.

Mr. Harrison was our friend when he was one of the Division Engineers engaged in the construction of Chicago's great canal. There we learned to admire his even, genial temper; his justice in dealing with those over whom he exercised authority; his sound and ripened judgment in all matters pertaining to his

profession. But others, too, were aware of these high qualities,—qualities which those others wished to employ in a wider field of usefulness. But we had reluctantly to part with him, even though we rejoiced to realize that others appreciated him as we did.

It was the melancholy privilege of one of us to attend a solemn service in the "Little Church Around the Corner," in New York, on September 15th last, when all that was mortal of our friend lay at the chancel steps in a casket banked with flowers. The church held a large company of people gathered there to pay their last tribute of respect to the man and the engineer. Some were brethren of the profession; some contractors who had tested at first hand his justice and his skill; and some were foremen on work which he had directed; but there we were, one sorrowing brotherhood for the departed engineer, friend and true man.

(Signed) L. K. SHERMAN,
ISHAM RANDOLPH,
E. H. LEE,
Committee.

HENRY FISHER WHITE, M. W. S. E.

Died October 28, 1912.

Henry Fisher White was born in Boston, Mass., October 14, 1851. His parents were J. Avery White and Elizabeth Fisher White.

His first engineering work was in the office of the City Engineer of Worcester, Mass. Afterwards he engaged in railroad work, first with the Fitchburg road, and later with the Boston and Albany.

In 1872 he came west and became Assistant Engineer upon the tunnel section of the Cairo and Vincennes railroad, where he remained for a year. He then was employed on surveys and construction of minor roads until 1876, when he became assistant to the Chief Engineer of the Burlington, Cedar Rapids and Northern, with headquarters at Cedar Rapids, Iowa, where for 25 years he was prominent as a citizen, interested in many of its enterprises, and where he married. He was a member there of the Congregational Church.

In 1881, he was appointed Chief Engineer of the road, which position he held until it was made a part of the Rock Island System. During the time he was Chief Engineer of the B. C. R. & N., it grew from 700 miles to 1,300 miles of splendidly-built and equipped road. In 1902 it was absorbed by the Rock Island System, and he became Engineer of Maintenance of Way of the larger system, occupying that position for six years.

Mr. White was known and loved for his sterling character, his patience and gentleness. He rarely exhibited any temper, or criticized, being ever ready to excuse the shortcomings of others. His work was recognized by quality and thoroughness, being always as good as conditions would permit.

His late residence has been in Chicago, but a larger part of his time was spent in looking after his interests in Colorado, where he was at the time he was taken ill and suddenly passed away. His wife and two daughters survive him.

Mr. White was a member of the American Society of Civil Engineers, the American Railway Engineering Association, and the Western Society of Engineers.

(Signed) G. DAVIS,
J. M. BROWN,
I. L. SIMMONS,
Committee.

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Extra Meeting, January 27, 1913.

An extra meeting of the Society (No. 810), being a meeting of the Electrical Section, W. S. E., held jointly with the Chicago Section, A. I. E. E., was held Monday evening, January 27, 1913.

The meeting was called to order at 8.25 p. m. by Mr. R. H. Rice, and with about 180 members and guests in attendance.

The minutes of the last meeting of the Section were read and approved. The announcement was made that this was the date for the election of three members of the Executive Committee of the Electrical Section, W. S. E., who had been nominated by petition at the last meeting, December 23, 1912, viz.: R. F. Schuchardt, chairman; F. J. Postel, vice-chairman; and P. B. Woodworth, member of the committee for three years. There being no objections, these were declared duly elected.

Mr. T. P. Gaylord, western manager of the Westinghouse Electric and Manufacturing Company, was introduced, who presented Mr. B. G. Lamme, chief engineer of that company. Mr. Lamme addressed the meeting on "The Desirability of Revising the Rating and Methods of Testing Electrical Apparatus." Discussion followed from Messrs. William B. Jackson, Hugh Patterson, W. C. Bauer, P. B. Woodworth, B. H. Glover, Mr. Van Hatten and Jos. H. Jacobson, with answers and closure from Mr. Lamme.

Meeting adjourned about 10.15 p. m.

Regular Meeting, February 3, 1913.

A regular meeting of the Society (No. 811) was held Monday evening, February 3, 1913. The meeting was called to order at 8.15 p. m., Vice-President A. Bement presiding, with about 75 members and guests in attendance. The reading of the minutes of the preceding regular meeting was dispensed with. The Secretary reported from the Board of Direction a list of applicants for membership as follows:

Charles E. DeLeuw, Chicago.

Fred B. Money, Gary, Ind., transfer from Junior.

Joseph C. Worrell, Minneapolis, Minn., transfer from Associate.

Clure M. Powell, Chicago.

Hyman M. Shulman, West Lafayette, Ind.

Don E. Marsh, Glencoe, Ill.

John L. McConnell, Chicago.

Jesse H. Libberton, Chicago.

Also a list of those elected into the Society at a recent meeting of the Board of Direction as follows:

Wm. T. Walters, Chicago.....	Junior	Member
W. S. Merrick, Chicago.....	Associate	Member
N. W. Halliday, Jr., Spartanburg, S. C.....	Junior	Member
Frank T. Leilich, Spartanburg, S. C.....	Associate	Member
Chas. H. Thompson, Champaign, Ill.....	Student	Member
Edward A. Hribal, Champaign, Ill.....	Student	Member
D. A. Tomlinson, North Chicago, Ill.....	Junior	Member
Bernard J. Klein, Chicago.....	Associate	Member
H. L. Boynton, Antigo, Wis., transfer to.....	Associate	Member
Walter H. Knapp, Milwaukee, Wis.....	Associate	Member
David B. Maver, Chicago.....	Junior	Member
Leonard H. Zeman, Chicago.....	Student	Member
Oscar R. Erickson, Chicago.....	Junior	Member
Edward S. Hanson, Chicago.....	Affiliated	Member
I. M. Clicquennoi, Chicago.....	Associate	Member
Robert F. Hall, Chicago.....	Affiliated	Member

The chairman then referred to the topic of the evening and introduced

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Mr. Jarvis Hunt, who addressed the meeting on "A Proposed Central Passenger and Freight Terminal for Chicago's Railroads." This was illustrated by a number of stereopticon views. Discussion followed from Messrs. W. H. Lyford, John M. Ewen, C. H. Cartledge, J. W. Mabbs, F. E. Davidson, with many questions, which were answered by Mr. Hunt and Mr. Lyford.

Meeting adjourned about 10.15 p. m.

Extra Meeting, February 10, 1913.

An extra meeting of the Society (No. 812), the Bridge and Structural Section, was held Monday evening, February 10, 1913. The meeting was called to order at 8.20 p. m., Mr. I. F. Stern, chairman of the Section, presiding and with about 55 members and guests in attendance.

At the request of the chairman, the Secretary read the paper, "Railway Bridge Design in Europe and America Compared," by Edward Godfrey, of Pittsburgh.

Discussion followed from the chairman, President Reichmann, C. R. Dart, W. F. Jordan, F. G. Vent, W. M. Wilson, E. B. Wilson, O. F. Dalstrom, P. W. Leisner, and W. S. Lacher.

Meeting adjourned soon after 10 p. m.

Extra Meeting, February 17, 1913.

An extra meeting of the Society (No. 813) was held Monday evening, February 17, 1913.

The meeting was called to order by President Reichmann at 8.25 p. m. with about 120 members and guests in attendance. As there was no business to be considered, the president introduced Mr. Roderick Peattie, who read his paper on "The Topography of the Bedrock Under Chicago." This was illustrated with a contour map and a relief map under glass, showing approximately the variations in the surface and elevation of the bedrock, the Niagara Limestone.

Discussion followed from Messrs. H. S. Baker, F. A. Smith, F. W. DeWolf, H. E. Goldberg, S. Montgomery, F. E. Davidson, G. C. Nimmons, Wirt F. Smith, J. W. Mabbs, J. C. Llewellyn, S. T. Smetters, Chas. E. Fox, U. S. Grant, S. J. Swanson, D. B. Ball, H. R. Abbott, G. B. Springer, S. Linderoth, with replies and explanations from Mr. Peattie.

Mr. F. E. Davidson offered a vote of thanks to Mr. Peattie for his interesting paper, which was approved by a rising vote.

Meeting adjourned about 10.15 p. m.

Extra Meeting, February 24, 1913.

An extra meeting of the Society (No. 814), a joint meeting of the Electrical Section, W. S. E., and the Chicago Section, A. I. E. E., was held Monday evening, February 24, 1913. The meeting was called to order at 8.20 p. m., with Mr. R. H. Rice, chairman, presiding and about 65 members and guests in attendance.

Mr. L. B. Andrus, general superintendent Indiana and Michigan Electric Company, South Bend, Ind., was introduced, who presented his paper, which had been issued in printed form by the A. I. E. E., New York, on "The Application of Synchronous Motors to a Water-power Transmission System for the Betterment of Service Standards."

Discussion followed from Messrs. R. H. Rice, R. F. Schuchardt, L. B. Andrus, E. W. Allen, W. B. Jackson, E. H. Freeman, C. W. Place, Mr. Drake and H. B. Bryden, with a closure from Mr. Andrus.

Meeting adjourned at 9.40 p. m.

J. H. WARDER, Secretary.

BOOK REVIEWS

THESE BOOKS ARE IN THE LIBRARY. W. S. E.

WATER, ITS PURIFICATION AND USE IN THE INDUSTRIES. By W. W. Christie, C. E. D. VanNostrand Company, New York. 1912. 5½ by 7¾ in.; pp. 219; illustrated. Price, \$2.00.

In view of the excellence of Mr. Christie's books on chimneys, the reviewer was sadly disappointed by this book on water. It is ear-marked by the track of scissors as well as a lack of research in abundant current literature. In the preface, the author apologizes for omitting the names of all manufacturers, yet the book could have more value if the names were given, and references added freely instead of mere assertions. Much of the data given are old, and some are out of date. Outside the mechanical descriptions, the author frequently glosses over the facts that should be commented upon. For instance, in speaking of "chlorine," no mention is made of the fact that salt wells or other natural sources may cause high chlorine, regardless of sewage pollution. Nor is mention made of bacteria in explaining the impurities in water, although bacteria are important, not only in drinking water, but occasionally in paper mills.

Cold and hot water processes of softening are discussed. A far better treatment of the cold softening problem will be found in the paper of J. O. Handy (Proc. Engrs. Soc. Western Penna., December, 1913, pp. 659-726).

Considerable space is given to pressure filters and particularly strainer cups, the details of which are elaborately described. In discussing the purification of water by sterilization and other processes, scant data are given. Curiously enough, aeration is mentioned as a means of purification, cooling ponds for condenser purposes being confused with aeration, really intended for biological purposes to remove odors or prevent anaerobic action. Sterilization by heat is discussed from a mechanical standpoint.

Evidently the author holds a brief against filtration of municipal supplies, for he attacks the filter plants of Washington and Philadelphia, thereby claiming that pathogenic germs multiply in municipal filters, since the typhoid rates have not markedly dropped. And yet a few pages later in the book the high bacterial efficiency of the Philadelphia filters is commented upon. A curious heading is "Alum as a Disinfectant," while in the chapter on filtration is included "Use of Tannin in Boilers." In the chapter on measurements of water, no reference is made to the Pitometer. Included in the chapter on "Oil in Boiler Water" are notes on the cost of pumping.

It is somewhat difficult to see how such books serve the public. The arrangement is poor, the information scanty and occasionally distorted, and considerable portions are not well chosen at times, the importance of lesser details are exaggerated, and essentials passed over or omitted. L. P.

THE RAILWAY LIBRARY. 1910. A Collection of Noteworthy Addresses and Papers, Mostly Delivered or Published During the Year Named. Compiled by Slason Thompson, Director, Bureau of Railways News and Statistics, Chicago. Published by the Bureau, 1911. 5½ by 8½ in. 458 pages. Cloth bound.

THE RAILWAY LIBRARY. 1911, and Statistics. Same author and publisher as above. 1912.

The first issue of this series, The Railway Library, 1909, was issued in 1910 and noted in the JOURNAL for October of that year (Vol. XV, page 691). The above two volumes form a valuable and welcome addition to our library, and it is hoped the series may be continued indefinitely, as the books are full of "good stuff" that deserves to be retained in this more permanent and stable form.

The 1910 volume opens with a condensation of the Introduction to the initial volume of Poor's Manual of the Railroads in the United States, published in 1868-69, a retrospect of the growth and development of our railroads

up to that date. This is a valuable historical contribution to the literature of our railroads. Then follows an interesting account of The First German Railway and the celebration of the seventy-fifth anniversary of its opening. This road is unique in being only 3.74 miles in length, connecting the old towns of Nuremberg and Furth, and during all this time it has maintained an independent position among the German railways and has not been extended beyond its original plans. From the report for the year 1909 it is learned that the capital cost per mile is \$122,457, that it owns eight locomotives and forty-one passenger and freight cars; that it carried 3,999,746 passengers in 1909 an average of 3.47 miles; that the gross earnings were \$99,959, with operating expenses of \$82,950, and that the road has ninety-one employees to whom was paid an average of \$382.00 for that year.

A valuable and extensive article in this book is the finding of Charles E. Otis, Esq., Special Master in Chancery, in The Minnesota Rate Case, which the railroad interests hope may be sustained by the United States Supreme Court. This paper is quite full and exhaustive of the subject; it takes up the question of costs or valuation of this public utility.

Following this article is a paper by President E. P. Ripley, of the A. T. and S. F. Ry. Company, on "The Railroads and the People," which originally appeared in the *Atlantic Monthly*. As would naturally be expected from such an author, the paper is an able presentation of the railroad side of the question. Another "Presidential Address" is from President Elliott of the N. P. Ry. on "Efficient Railway Management," which was brought out by the widely spread statement attributed to Mr. Louis R. Brandeis, of Boston, that by *efficient management* the railroads of the country could save \$1,000,000 a day. Following this statement the Interstate Commerce Commission made some investigations and gave an opinion which effectively denied the statement that the railroads could pay a substantial increase in wages without attempting an increase in revenue by advance of freight rates, simply by more efficient management and the saving of \$1,000,000 a day.

Mr. Frank Trumbull, who addressed this Society at one of its annual dinners in such an admirable manner, also contributes a very readable paper on "Efficiency," an address to the Canadian Club of New York, March 14, 1911. Again, William J. Cunningham, of Harvard University, contributes a valuable paper on "Scientific Management of Railroads." The author of this paper shows the wide divergence between regular shop work which is capable of being analyzed and systematized with a resultant economy of operation, and the operation of railroads. The conditions are so different.

The question of freight rates, "The Necessity for Higher Rates," is well presented by James McCrea, president of the Pennsylvania Railroad Company, before the Interstate Commerce Commission, Washington, D. C., October 12, 1910, and is worthy of careful reading. Mr. Martin A. Knapp, chairman of the Interstate Commerce Commission, contributes two addresses on "The Needs of the Railways," which, from such a source, are worthy of serious consideration.

Turning now to matters of importance and interest to the great mass of the people of this country, the farmers, the Secretary of Agriculture, the Hon. James Wilson, in his report of his department for 1910, gives his views on "The Farmers' Share of the Consumers' Cost," which is related directly to "The High Cost of Living" in this country. To this subject also, Mr. B. F. Yoakum, a well-known railroad man, contributes a chapter on "The Farmer and the Cost of Living."

The statement has been made from time to time that the railroads do not get sufficient pay for the transportation of the railway mail cars, with their attendant mail clerks and mail. This is interestingly brought out in eight pages of "Railway Mail Pay Primer." The figures therein are interesting and startling to the average layman.

An interesting chapter is contributed by Mr. Howard Elliott, of the Northern Pacific Railway Company, on "Co-operation Between the Railway Owner, the Railway Employee, and the Railway User," an address at Helena,

Mont., in 1910, wherein he shows how the great mass of our people which are included in one or another of the three classes mentioned, would be materially benefited by a better understanding of the relations which exist between them and what could be done by co-operation.

Our own Mr. F. A. Delano, president of the Wabash Railroad, made a valuable address to the National Rivers and Harbors Congress at Washington, December 8, 1910, on "Waterways, Their Limitations and Possibilities." From foreign sources there is presented two papers on "Government Ownership of Railways," its failure in Australia, by A. W. Pearce, and in France by W. P. Simons. Dr. James L. Laughlin, of the University of Chicago, made a notable speech in Chicago, December 10, 1910, on "The People's Investment in Railways," which is printed in this collection of railway papers.

Mr. A. J. County, of the Pennsylvania Railroad Company, contributes an interesting paper on "Railway Accounts and Statistics in the United States," which is followed by another essay, "The A, B, C of Railway Capitalization," by Frank Nay, of the Rock Island Lines. There is herein also a translation from a German railway publication, a paper by Mr. Hoogen on "Automatic Signals on German Railways." There is an illustrated article on the "New Pennsylvania Terminal in New York" which gives a good idea of this "Monumental Passenger Station."

A memoir of Edward Henry Harriman, delivered in New York, January 25, 1911, by Mr. Otto H. Kahn, gives one some idea of the personal peculiarities of that great railroad man, and should be of value to those interested in the history of railroad organization and management. Finally, Mr. Slason Thompson contributes some 21 pages of "Statistics of American Railways," for the year ending June 30, 1910, which contain a great deal of valuable tabular matter, pertaining, among other things, to "Railway Mileage in 1910," "Equipment," "Employees and Their Compensation," "Capitalization," "Cost of Construction," "Ownership," "Public Service," "Earnings and Expenses," "Taxes," "Accidents," etc. An index of 5 pages concludes the volume.

The third volume of this series, noted at the beginning of this as for 1911, is similar in general character to the preceding, opening with a very interesting account of "Travel from Detroit to Chicago in 1833." It is hard for a present day resident of this city to comprehend and absorb these extracts from some early letters. Another historical contribution to these papers is by S. M. Philp on "British Railways Eighty Years Ago." "The First Report of the Interstate Commerce Commission," by Judge Thomas M. Cooley, dated December 1, 1887, is of considerable historic value, as is also "Regulation of Interstate Commerce," abstracts of three addresses by the Hon. Martin A. Knapp, given in 1911. Other papers relating to the same general subject are "The Commission Above the Courts," by the Hon. Charles A. Prouty; "The Railroad Traffic Manager," by the Hon. Franklin K. Lane; "Railroad Securities," by a commission with Arthur T. Hadley, chairman. This book also contains the report by George F. Swain on "The Physical Valuation of the New York, New Haven & Hartford Railroad Company," which has much of interest to railway men. These papers and others following show the present day interest in government ownership of railways. Mr. W. M. Acworth contributes "Prospects of State Ownership in England and in the United States"; W. F. Allen, of the American Railway Association, writes on "Railways and Naturalization in the United States," and Fairfax Harrison, president C. I. & L. Ry. Co., on "Government Ownership of the Railways as Unnecessary and Undesirable."

Mr. Julius Kruttschnitt, of the Union Pacific System, gave an address at Harvard on "Efficient Public Service of the Railways," which is printed among these papers. Also Mr. Howard Elliott, of the Northern Pacific Railway, made an address in Minneapolis on "Public Opinion, Its Effect on Business." "The Railway Mail Service" is presented by Mr. H. P. Thrall,

which further amplifies what was written on this subject in the volume for 1910. "The State Railways of France" is presented by Marc de Valette, of Paris. An illustrated article tells of "Chicago's Greatest Passenger Station," which has been so well described in this periodical for December, 1911. The book concludes with some 120 pages, "Statistics of American Railways for 1911," also prepared by the editor of these two books. A notice at the beginning of the volume states that the 1909 edition can be purchased for \$1.50, the 1910 for \$1.00 and the latest volume for 1911 for 50 cents, of the Bureau of Railway News and Statistics, in the Railway Exchange.

MEMBERSHIP

Additions:

Boynton, Herbert L., Antigo, Wis., transfer from Junior to Associate	Member
Clicquennoi, I. M., Chicago.....	Associate Member
Erickson, Oscar R., Chicago.....	Junior Member
Hall, Robert F., Chicago.....	Affiliated Member
Halliday, N. W., Jr., Spartanburg, S. C.....	Junior Member
Hanson, Edward S., Chicago.....	Affiliated Member
Hribal, Edward A., Champaign, Ill.....	Student Member
Klein, Bernard J., Chicago.....	Associate Member
Knapp, Walter H., Milwaukee, Wis.....	Associate Member
Leilich, Frank T., Spartanburg, S. C.....	Associate Member
Maver, David B., Chicago.....	Junior Member
Merick, W. S., Chicago.....	Associate Member
Thompson, Chas. H., Champaign, Ill.....	Student Member
Tomlinson, Daniel A., North Chicago, Ill.....	Junior Member
Walters, Wm. T., Chicago.....	Junior Member
Zeman, Leonard H., Chicago.....	Student Member

Changes of Address:

Aiken, Vernon H., Enderlin, N. D.
 Armsby, Chas. L., State College, Pa.
 Baker, Homer S., 203 Third Ave., Peoria, Ill.
 Bayer, E. J., 331 N. Walnut Ave., Sidney, Ohio.
 Bayliss, John Y., 1013 Harrison St., Lynchburg, Va.
 Blakely, A. J., Chandler, Ariz.
 Dose, H. F., care Engineers' Club, New York, N. Y.
 Fry, George W., 504 Bliss Bldg., Tulsa, Okla.
 Green, Edward A., Gregory, Texas.
 Hasselfeldt, E. C., 2122 Seminary Ave., Chicago.
 Jutton, Lee, 117 Willis Ave., Ashland, Wis.
 King, Frank E., C. M. & St. P. Depot, Minneapolis, Minn.
 Macdonald, F. A., Armstrong, Iowa.
 Potts, Frederick A., 2211 Cedar St., Milwaukee, Wis.
 Stevens, Hubert A., City Engineer, Corpus Christi, Texas.
 Weaver, H. P., 1148 Peoples Gas Bldg., Chicago.

Deaths:

Robert B. Seymour, Oak Park, Ill.....February 22, 1913

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FUTURE PROBLEMS OF ELECTRICAL ENGINEERING

DR. C. P. STEINMETZ.

*Presented at a Joint Meeting of the Electrical Section W. S. E.
and the Chicago Section A. I. E. E., October 25, 1912.*

The subject on which I desire to say a few words is, Future Problems of Electrical Engineering. The nature of the subject naturally is such that it must be to a large extent guess-work, a kind of a dream. At the same time, it is not entirely a dream, because we find today certain very pronounced tendencies in the development of the applications of electricity as represented by the modern central station, tendencies which are not incidental, but which are based on economic laws, and therefore must continue in the same direction, so that we may estimate as to what the development in the future will be. These tendencies are toward the separation of the utilization of electric power from its generation, and the concentration of the generation, for all purposes of use, into one unified system, and the other tendency, which is very marked, is the concentration and consolidation of the electric power generation of different places, or an entire territory into one system. The primary force which leads to these tendencies naturally is the superior efficiency of power generation in large bulk, and the higher economy resulting from the better load factor, which is the result of the higher diversity factor, when supplying power to a considerable number of different users. Furthermore, it is the advantage of separating the generation from the utilization.

Naturally, in the beginning, where electric power was used for railroad operation, for general distribution, for driving factories and mills, the power was generated at the premises, but, on the other hand, when the mill or the railway has its own power house, naturally the economy must be less, due to the smaller amount of power generated, but still more so, the economy must be less, due to the poor load factor. But more dominating, perhaps, than either of these two reasons, is the lesser efficiency of administration in the case where the power generated is incidental to some other industrial operation. The administration or management of a mill or factory naturally cannot as efficiently administer and direct an electric light and power generating plant, as can a company

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which makes that class of work its specialty, so the result has been and is that the economy of the unified generating system is of such a character that power can be sold in many cases cheaper than it can be generated by the consumer, and this necessarily leads to the abandonment of generation by the user of the power and the buying of power from the central station.

On the other hand, the small station supplying a village or a township, naturally is at a disadvantage compared with the larger system, so that we see gradually the smaller generating systems which existed all over the country being replaced by the corporation which operates a territory; and similarly, the different competing electric light generating systems of a large city, getting together in a large city supply system. There are, then, the unified supply systems stretching out into the adjoining territory over the state, and finally, possibly, over the continent. Naturally the city supply system, the city generating station, when extending over and developing a territory, is at an advantage over the mere territorial supply company, because it is a center, a focal point, in the big power house, and the big system of the city, and it has the advantage, furthermore, of the diversity factor between the city load and the country load.

Now, when we look around, we see this tendency at play all over the country, and it is well for us to estimate how, with the same laws operating, it must continue and to what results it must lead.

But, further still, we can make an estimate concerning the system which is developing because we see its beginning. Naturally, when the city station spreads out its lines, its feeders into other territory, takes in the supply which formerly was provided by the local station, the generating machinery in the local station usually to a large extent goes into the scrap pile. As a rule, it has approached the end of its useful life or very soon reaches it. Some of it remains as reserve plant. Occasionally, the new and more modern machinery, some medium sized turbo-alternator, may remain as a part of the modern station, for further out a turbo station may be installed, guarding the ends of long feeders stretching out from the city power house. So you see in many places from the main huge power house of the city, feeders stretch over the country twenty or thirty miles, and terminate in a local outlying generating station, a station small compared with the city station, but large, possibly, compared with the station which would supply, or be sufficient to supply, the local demand.

Carrying that development further, the systems probably will spread further across the country until they approach each other's territory and then, since co-operation is more economical than competition, they will join together, will be interconnected by trunk lines, so that finally we may expect in the electric power supply, in the electrical development of the country, a similar condition as

has taken place in the railway systems of the country, a network covering the country, with centers of generation and centers of utilization.

The distribution system has remained unchanged now for a generation, and all evidence is in the direction that it will remain the same,—the same 220 volt, 3-wire Edison system either on direct current from converters in substations, or on alternating current through transformers from 2200 volt primary distribution. But, instead of reaching out from local power stations, we see the distribution system fed by power feeders coming from the generating station, and these generating stations are interconnected with each other by trunk lines, transmission lines. Now, as to the latter class of transmission lines, we can also make an estimate of the probable voltage. The voltage of these interconnecting trunk lines will probably be between 100,000 and 160,000 volts, rather nearer the latter voltage, because it will be the highest voltage at which heavy trunk lines can be operated without causing inconvenience, without requiring special arrangements to guard against corona losses, against the escape of power into the air. The voltage which is less certain is that intermediate between the transmission and trunk lines, of the distribution system, the power feeder.

Now, a considerable part of the power naturally finds its use in large cities by underground distribution systems, underground power feeders. There we have cables. It is very probable that one of the distribution voltages will be the generation voltage, which, in accordance with our present tendency, probably is around 10,000 volts, so that the distribution feeders from the generating station will supply the power at or around 10,000 volts to the substations from which radiate the distribution systems.

But even there, undoubtedly, a higher distribution voltage of transmission feeders will be necessary, and to a considerable extent 20,000 or 30,000 volt underground cables are beginning to be used as interconnecting long distance feeders. To cross the country by overhead lines, higher voltage will naturally be necessary, probably 30,000 to 60,000 volts, as distribution and transmission feeders intermediate between the very high voltage trunk lines and the 2200 volt distribution. There we also see the beginning.

The question which arises is: What will be the transformation losses within the system? From the generating system we step down to the primary distribution voltage of 2200 and once more transform into the secondary distribution of 220. Estimating as an average 2% loss in the transformation (it will be possibly a little more in the small units and a little less in the large units, but that may constitute a fair average), you see that between the generating station and the consumers' premises you have a transformation loss of about 4%. Where the power goes through transmission feeders, through 30,000 volt cables, or through 30,000 or 60,000 volt overhead lines, we get an additional loss in the step-up

transformer. Occasionally, an additional transformation loss in stepping down to the distribution feeder is incurred, although usually we will be able to step down directly to the primary distribution of 2200 volts.

That means in those cases at greater distance from the power house we may expect from 6 to 8% transformation losses.

In the case of power which comes over the high voltage trunk lines, over long distances from the water power sites to the city, or from city to city, that power you see meets an additional transformation loss, and we may expect (depending on how many transformations we have—whether we are able to transform directly to the generating station from the 150,000 volt trunk line, whether we can transform directly down to the 2200 volt distribution, or whether we have to go into distribution feeders at 10,000 or 30,000 volts), from 8 to 12% loss. Naturally we find the loss varying with the load on the conductor, the I^2R losses of the line, which, as a whole, probably would not exceed 10%. That means in some cases, as where the power comes over the trunk line, we may reach a material loss, but it is obvious that these long distance trunk lines will not be carrying the power in the same direction continuously, but will rather act in carrying the power as interconnecting lines similarly as you had in the old Edison systems, tie-feeders or tie lines between the generating stations which carry the energy in one direction or the other direction, depending on the conditions of the load. So also the function of the trunk lines will be to take care of the peak loads, to get the benefit of the diversity factor of the different parts of the system, the different generating stations and their territory, and at the peak load the cost of power production is so far in excess of the average cost that you can well afford, for the purpose of cutting off the peak, to incur a loss of 10 or 20% even, in the power, and still get the power very much cheaper than if you had to provide all the generation. Continuing that still further, assuming then that we have a system covering the country, with trunk lines and distribution systems, we meet still further diversity factors. Finally, we get a diversity factor of terrestrial rotation. Assuming even that, for instance, New York City and Chicago had identically the same load curve; if you could interconnect them by a trunk line, you would get a diversity factor, due to the time difference between the cities. Now, that looks, at first sight, very far ahead, but we should realize that lines radiating from Niagara Falls, say, to Erie on one side, and Syracuse on the other side, meet a variation of one hour in time, so if you would supply all the energy of Erie and all the energy of Syracuse, and even if those two cities had identically the same load curve, you would get a diversity factor due to the time difference today.

Naturally, before that will be accomplished some changes will have to take place—changes in our industrial and in our political

condition. Obviously, when electric power generation, transformation and distribution are as essential for the welfare of the country as are the freight and passenger transfer and distribution by our railway systems today, then it will no longer be permissible for any farmer or any village council to stop the electric transmission lines from being installed and operated. That means that the electric power system must have the same right of condemnation which the steam railway has today, and for the same reason, and with the same moral force. There is no sensible argument why these organizations, these systems which take care of the transfer and distribution of freight, should have the right of condemnation, while those which take care of the transfer and distribution of energy should not have it. The one is just as much a public utility and a public necessity as the other, and they should be considered exactly on the same basis. I believe that before the Twentieth Century has advanced any considerable extent, we will have a code of laws produced in accordance with the conditions of the Twentieth Century, and not a mixture of laws and rulings representing decisions from the time of Alfred the Great and William the Conqueror up to the days when the New Englanders burned their witches.

Then, another feature which will require numerical representation is the reliability factor, the continuity of service. There is a material difference in different classes of use of electric power, which is not sharply represented mathematically, which is very little understood by the non-electrical man, and even not very much understood by many electrical men, who are very far distant from operating engineering; that is how the cost of electric power depends upon the requirement of reliability and continuity of service. It is difficult to explain to the layman why one station at the end of a transmission line, or water power system, should be willing to supply city arc lamps at \$25.00 or \$30.00 a year, while another much larger system must insist on a higher price, with steam reserve, and possibly storage battery reserve.

Some classes of use of electric power require absolute reliability; for instance, the distribution in a large city. A short cessation of power supply may leave the elevators in a large office building hanging between the floors, much to the inconvenience and annoyance of the people in the elevators; if the lights go out in a theatre a panic with serious loss of life is liable to result, so that in such cases the highest reliability or continuity of service is required. In many other uses of power, a short intermission in the service, while it may be objectionable, would not be as disastrous. If, in surface railway service the power goes off for five or ten minutes, it is exceedingly annoying, but no disaster will result from that. It is not such a serious matter. If in a factory or mill the power fails for a few minutes, it merely means that some hundreds of thousands of men are idle for a few minutes, which is bad enough, but is not so disastrous a thing as having a crowded theatre left in dark-

ness. But in this case, if the power should fail for a day, and the railway system of a city be paralyzed and the mills and factories shut down, it would be very serious.

Again, other uses of electric power may not even permit shutting down for the shortest possible duration, even for the fraction of a minute, while a shut down for days and weeks, when previously announced, may not be serious. For instance, in the case of some electrochemical industries, where the electric furnace is used, if the power is off for a quarter of a minute the furnace may be frozen, the charge lost, and often the furnace also. There, absolute continuity is essential, but it may not be a serious matter if, during the time of heavy peak loads, or during the time that the rivers run dry, the electrochemical work has to shut down, even for several weeks, provided it is known beforehand and they can take proper care of their furnaces.

So you will see that different classes of electric power use are materially different as regards their reaction and the effect of a momentary shut down, a previously unannounced shut down for a considerable time; that is one of the dominating features in the cost of power and also in controlling the load factor of the system, as we have to provide for the power which must always be there.

Let us consider the case of such a development of one big system supplying all the power used by the community—what is the object, what is the reason, why that should be more economical; what are the forces which tend to bring this about? The superior economy of production of electric power in large bodies is no longer the dominating reason, because when we get to stations of 100,000 kw. capacity, or to systems of 100,000 kw. capacity, there even today in one and the same system we always have several power houses, because the economy of the 200,000 kw. station is not materially greater than that of the 100,000 kw. station, as far as the operation of the station is concerned. So it is no longer the higher economy of generation, but the advantage is the higher load factor which a big system secures, due to the diversity factor of the different classes of load. That is what gives the superior economy. This has been pointed out by Mr. Samuel Insull, in his paper before the American Institute of Electrical Engineers, where he gave conclusive evidence of it. But at the same time I do not believe that is the only reason of the superior system. I even question whether this is the foremost reason, because the advantage of the better load factor of the big, unified system, while it is considerable, does not seem to me to be as great as the experience shows the economic superiority of the big system to be, and I believe one of the dominating causes of the economic advantage of the big system is what I may call the diversity factor of the operating staff. It is that, in such a big system, we can have an operating staff, we can have engineers, electrical, mechanical and steam engineers, administrative men, business men, financial men, of a high class, of

a high character, which could not be afforded in a smaller system, and that, as a result thereof, through all the various activities of generation, transmission, production, accounting, etc., we can have in the big system the highest talent, the highest authority in their respective fields, and therein the smaller system necessarily fails. A small system may have one or two good men, which may be authorities in a certain field, and in that particular direction wherein they are authorities that system may be leading, but no single man, or even a couple of men, can cover the entire field of activity. So any such system must be very materially weaker, inferior, less efficient, than the big system which can afford to have, and does have, the best men in the various activities underlying the system, and in my opinion that is the most essential thing, which gives the superior economic advantages to the big systems.

One of the evidences to my mind that this is the foremost reason is that we do not find in all the big systems this superior economic advantage. We find water power, big water power or railway systems, which have just as good diversity factors, which supply electric energy for general distribution to cities, to factories, or mills, and which therefore should have the same economic advantage, but which in their economic success, as represented by their financial and other strength, are vastly inferior to the big Edison systems. I believe one of the most valuable assets of the days of Edison, that he preached in the early days, when the Edison systems were first started, was that the very best engineers and administrative men in their field were none too good to operate the systems,—that it is far more economical to get the best men than to try to get along with cheaper men, with cheaper help, with second-class men operating a large system. I think that is one of the valuable assets brought over to our times, to our Edison companies, from the days of Edison and his control of the industry. This makes it possible to have these systems in every respect not only as efficient, but as modern as possible, and the greatest claim a system can make is that it is thoroughly up to date, that it is entirely modern; and no system can be that which has not the highest authorities in all important activities, attached to itself. In regard to these big systems which are spread all over the country, gathering in all the power generation, we find they are not only up to date in all the activities pertaining to the business, but they are ahead of the development. They are utilizing not merely all the advances of electrical engineering, but they are leading the advances, and creating advances, and we see that some of the important work in recent years has been done by the big operating companies by themselves, or, very often, in co-operation with the manufacturers. I may cite, for instance, the case of the aluminum cell lightning protection, which has been developed jointly by an operating company and a manufacturing company. In this connection I need only refer you to the modern method of protection

and control of these huge systems, to the development of the power-limiting reactance, and all the way along to the oil switch controlling vast quantities of power, which problems have been experimented upon and carried out successfully jointly by a big operating company and the manufacturing company. No small company can do that financially, and even if it could do it financially, it could not do it from an intellectual standpoint, because no small company can have the engineering talent to carry out this development work, can have the administrative financial talent to see the necessity of it and realize ahead of time that it is a very good investment to offer a 12,000 kw. generator to be short circuited any number of times to see what will happen to it.

So in this direction today, by these big generating and operating companies industrial advance is carried out in the field of electrical engineering, but, after all, what is being done at present probably is only a very crude beginning of what we may expect to see in the future and probably not in the very distant future, either.

What these big systems do today is, they gather in all the industries which are users of large power, supply electric power to them, and so secure the best load factor which can be secured by the overlapping of the load factor or power demand of all the industries which are available. But there is a limit then. We get, under such conditions, a load factor which is very much better than any individual industry has, but still it is frightfully low, very far from unity. There is now the next step to be taken.

Thus far the engineering work and developing work done by the operating companies is only in those lines and those directions which are of direct importance to the operation of the system. The next step will be to go beyond that, to go into the development and control and advance of those industries which are users of power, and not merely overlap the load curve of the various industries, but control and modify the load curves of the industries, so as to get entire overlapping and close approach to the unity load factor, and that is the next step in advance which is available and feasible. It means going into the study of industrial conditions, it means that operating companies must not only have attached to them, on their staffs, the highest authorities in all the various fields of electrical engineering, administration, etc., in all those fields which are of direct importance in the activities of the company, but attached thereto should also be the highest authorities in those industrial fields which are users of power, so that they can control and direct that industry. After all, if you think it over, the load factor of the various industries which utilize power is not invariable, but is incidental, and to a considerable extent merely the result of those conditions under which the industry has been developed. But with the change of the conditions under which an industry operates, with the change of the power supply, to your central station, they change also the conditions which determine the load factor of the

industry, which determine maximum efficiency, as regards the carrying out of the industry. These conditions are more or less modified by circumstances beyond the control of the company, but this work of going into the industry and seeing how the industry can be controlled, made more efficient by the use of central station power, cannot be done by the leaders in those industries, but must be done by the central station men, by the operating engineers under the direction of the operating company, because they are the only ones who are competent, or would be competent in that direction.

There is a very wide field. Select any industry you choose, and see how these principles could be applied to that industry. It means study—it means, probably, the establishment of industrial research laboratories connected with, or under the direction of, the operating companies carrying out this work, and it is not such an entirely new idea. To some extent it is old. On a small scale it is taking place today, not only in the electrical industry, but in railroading also. The railroads do not simply gather in the traffic. They create traffic. Some railroads interest themselves in the operation of experimental farms—they are not interested directly in investment in farm lands, they are interested merely in improving the load factor of the railway, as we may state it from our point of view.

Let me give you an instance, as this matter is applied to the central station company; we hear that there is abroad, in Norway, an industry for the production of nitrate fertilizer, using a vast amount of electrical power; hundreds of thousands of kilowatts are used, at a very good profit, to produce nitrate fertilizers. Now, the central stations are looking for users of power, so it is natural that those interested in electrical operation should look into this industry. An expert engineer was sent over to Norway to study that industry. He carefully looked into it, learned the conditions under which this industry is productive, found the investment required, etc., and then came to the conclusion that in the industry as it is carried out abroad the investment is so great that the interest on the investment is a very large part of the cost of the product, the nitrate fertilizers. This means that the plant must be used continuously, and an intermittent use, even if intermittent only for a relatively small part of the time, due to the increased interest and investment charge on the shortened time of use of the plant, very soon makes the industry unprofitable, so that very soon you get to a condition, with the intermittent use of power, that even if the power costs nothing, it would not pay to make nitrate fertilizers, because the interest on the investment would be more than the profit. There the investigation ends. The conclusion is that this industry is not suited for taking care of spare power for improving the load factor of our operating systems.

Now, there it should not end, but the problem should go over

to the industrial research laboratories of the operating company to look into it, study the industry, and see why the investment should be so enormous, and whether the industry could be developed further so as to reduce the investment, and thereby bring it within the field of economic use for intermittent power. It should be studied whether by a sacrifice of efficiency we could reduce the investment, how much efficiency would have to be sacrificed in cutting down the investment 25, 50 or 75%. In short, it should be the beginning of a study of the industry, its development for maximum efficiency of power utilization. Incidental to that, this would also give, to some extent, the control of the industry to the operating company which makes the investment in the research. Another instance is to be found in the electrochemical industry. In electrochemical industries continuity of service often is very essential, but it may be questioned whether such industries could not be carried out profitably, with a shut down for a month or two months during that period where the power taken from the water power fails by the rivers running dry. This would make it possible to economically utilize water-powers, by using them at any time when such water-power is available. Naturally, the question arises, when you shut down such an industry for a month or two months, what to do with the workmen and the staff of the industry. At the same time, in the chemical industries we often find a very small number of employes controlling and directing the use of vast power. We may find a 100,000 kw. station used and controlled by a dozen men or so. Now with 100,000 kw., if you can reduce the cost of power by 1/100 of a cent per kw. hr., that means \$10.00 an hour. You might give your staff a month or two months vacation, with full pay, if thereby in shutting down the industry for a month or two you could reduce the cost of power even by 1/100 of a cent per kw. hr.

That requires further study. There comes in the investment. It is not merely a question of the wages of employes. It is also that of the investment lying idle. But if, with a 100,000 kw. plant, you can, by allowing the investment to lie idle for a month or two, reduce the cost of power by 1/100 of a cent per kw. hr., it means a saving of \$70,000 per year, and that represents interest for two months on an investment of nearly \$8,000,000. If, therefore, under these conditions, you could, by shutting down for two months, reduce the cost of power by 1/100 of a cent per kw. hr., it would pay to shut it down, with an investment up to \$8,000,000. But all these questions require investigation and study, and the study must be made by the operating company, or by authorities in the particular industry which are under the direction of the operating companies.

In this direction I believe there is a possibility of a gradual improvement of the load factor beyond the values which we considered feasible in the past, and do consider feasible now, improving it by modifying the load factors of the industries so as to cause

them to overlap, to bring about a resultant very closely approaching unity.

To conclude, then, the tendencies which we see today are the separation of the use of electric power from its generation, the concentration of the generation of power for all purposes in a large territory, in one big unified system.

Continuing, we further expect to see electric systems covering the country like the railway systems cover it now, and to bring that about it means that we must extend our activities beyond those of merely generating and supplying electric power. It is up to us to improve the load factor by controlling the load factor of the industries, by taking an active interest in the control, direction, and advance of those industrial operations which are users of power.

This is not so far away. In manufacturing companies which are somewhat further distant from the industry than you are, although they benefit from it also, we find such research laboratories and research work going on in fields which are not of direct utility to the manufacturing company, but which are of utility to the electrical industry, and these efforts advance the industry by the increased demand for electrical machinery, and the manufacturer is thereby benefited, so that problems like the nitrate fertilizer production are being studied by research laboratories maintained by the manufacturers. But more directly interested, and more directly benefited by the result of such research work are the operating companies, and that is one of the suggestions I wish to bring to you as something the near future should see accomplished.

CONCRETE ROADS

EDWARD N. HINES.*

Presented January 20, 1913.

(This very informal address was illustrated with many lantern slide views, only a few of which are reproduced.)

The laws of Michigan relating to roads are somewhat different from those of other states. We have what are known as the state aid or state reward road law and the county road law. The county road law provides that the county shall be the unit in the construction of such roads as the county may be willing to take over as county roads. It is a law that was placed on the statute books of the state of Michigan back in 1893, and has been amended at various times since. While it is not the best road law that could be written, it was the best law that could be adopted and came more nearly meeting public sentiment as it existed at the time of its adoption.

There are eighty-three counties in the state, and Wayne was the twenty-seventh county to adopt the county road law. There are now forty-three counties under the law and others are coming in rapidly. The provisions of the law make it largely a home rule measure. Before it was amended some years ago it provided that before any county could come under this law the Board of Supervisors, which is the legislative body of the county, might take voluntary action to submit the law to the people, or they could be compelled to submit it to the people under a petition signed by ten freeholders from each township, incorporated village, and city in the county. Interested citizens of Wayne County worked for five or six years before ten such signatures could be secured from each township, village and city. When the law was submitted, it was adopted by a vote of approximately 40,000 to 7,000. Despite this overwhelming vote, some persons believed that the people did not know what they were voting on.

The County Road Commissioners (a board of three provided to carry on the work) are in the first instance appointed by the Board of Supervisors to serve until the next general election, after which they are elected. Henry Ford, the automobile man, Cass Benton, of Northville, and the speaker constituted the first Board of County Road Commissioners in Wayne County. We started in by recommending a tax for county road purposes and began to fix up the mudholes of Wayne County, but were stopped by an injunction proceeding. We went to court and won. After the tax was levied we were again stopped by an injunction proceeding. We went to court again and won. Then *quo warranto* proceedings were started against us. We thought it was about time for us to

*Chairman, Board of County Road Commissioners, Wayne County, Michigan.

do something, so we contracted a debt of \$25.00. The Board of County Auditors refused to pay it and we mandamused them. We lost the decision in the circuit court and carried it to the supreme court. The supreme court partly decided against us. Almost everybody started to run but me. I was so nearly across the river, however, I thought I might as well go on as to go back; so I kept right on for the other side. We then went to Lansing and presented amendments along the lines where the supreme court had indicated that the law was weak or ineffective, and secured their adoption by the legislature and their signature by the Governor.

It was then necessary to go back home and petition for a special session of the Board of County Supervisors, at which time a new Board of County Commissioners was appointed, consisting of John S. Haggerty, William Murdoch, and myself. We again started to get busy. The Board of County Auditors again refused to pay our account and we again mandamused them. By that time a year had rolled around with no improvement in our roads, so we got the warring factions together, and recommended that the entire tax levy be paid back. Our suggestion was adopted, but when we attempted to carry out this plan we found there was no legal way to pay back the tax. We again appealed to the legislature and got an enabling act passed so that we could pay it back, and a new levy of a quarter of a mill was authorized.

Our first experience was along the line of bituminous macadam construction. That seemed to be, at that time, the "last word" in road construction down East. We followed their specifications closely, but with the enormous traffic which our main, leading highways out of the city of Detroit were called upon to carry, we found in Wayne County, as is being found all over the country, that the automobile rapidly scatters the roads over the fences and into the ditches in fine particles. Instead of continuing to build a type of road which we felt was not a success, in our locality at least, we looked around to see what we could do to save ourselves from a constantly increasing maintenance charge and a constantly deteriorating road; from observation based upon the experiences of near-by country towns with bridge floors and with cross walks built of light concrete construction, we decided that concrete would solve the problem for us.

I might state in this connection that before we adopted concrete we built rock asphalt, we built brick, we built tar macadam, we built asphalt macadam, and we built plain water bonded macadam. Our experience was unsatisfactory in all those materials with the exception of brick, and the cost of brick in our locality for our purposes, is prohibitive.

We devised the concrete road, of which we now have about 65 miles. During the coming year, 1913, we expect to add some 40 odd miles, and from our experience we are not going to build anything else but concrete. We believe, with the past five years as a

guide, that a concrete road is a practical and economical form of construction which merits and is going to receive a great deal more attention in the future than it has received in the past.

Wayne County is in a valley, is flat, and not easily drained. It consists largely of a clay subsoil. Here and there we strike stretches of sand, but clay predominates. It is a common occurrence on the unimproved roads of Wayne County to be obliged to pry oneself out of the mud.

At an ordinary rate of speed the automobile has no effect on a macadam road; in fact, I doubt if it has as much effect as a horse-drawn vehicle. But as the speed of the automobile increases, it begins to tear up the road, causing clouds of dust, that is, road material, to scatter over the countryside. The theory of the macadam road is, as you know, that the abrasion of the horses' hoofs and the abrasion of the steel tires makes enough small particles to act as a cementing material to hold the road, but the automobile comes along and scatters the fine particles over the countryside; the faster it goes, the more dust, and the people who use the roads are not going to put up with the clouds of dust, let alone paying to replace the material that is being blown off by the automobiles and other vehicles. Riding behind a cloud of dust of that character is not only unsanitary, but it is a dangerous proposition. If you could see the horse drawn vehicles moving along the concrete roads with the tugs tightening and loosening as they go along, you would be satisfied as to the easy traction on these roads. They are not only dustless in summer but mudless at all times. They afford good traction for all types of vehicles. The drier the weather the less dust there is on the roads. What dust you find on the concrete road is dragged on from the side roads in muddy weather.

Michigan Avenue is of concrete construction, is in its third year, and reaches 22 miles out in an unbroken stretch except through the villages of Dearborn and Wayne.

A feature in favor of the concrete road is the small crown necessary to get rid of surface water,— $\frac{1}{4}$ in. to the foot. A horse cannot come along and pick out a track. He must be driven, irrespective of what part of the road he is on, and the driver is comfortably seated. On the ordinary type of macadam road the driver keeps up on the crown of the road so that he can ride comfortably on the seat.

The River Rouge runs along the side of this particular stretch of road. It is one of the few rivers in Wayne County that overflows its bank and washes under the road, but the concrete roadway bridges over all and does not "wash out."

We have three buildings in which we house our equipment and make our repairs. We keep on hand a stock of small parts that are liable to be broken, and manufacture our own concrete drain pipe, of which we use large quantities. This work is going on all the time.

The hauling of materials is done largely with hauling wagons drawn by traction engines. During our busy season last summer we employed about twelve hundred men. We find, as we get away from the centers of population, it is difficult to take care of our men and it becomes necessary to house and feed them in camps along the roadside.

As an index to the efficiency of our organization, we handle 1000 cars per month, spent \$600,000 during the road building season of 1912, take care of a voluminous correspondence, and look after the detail of this work, with four people in our office, at an expense to the county of \$6,223 last year.

This will give you some idea of the systematic methods that are employed. We believe that it is desirable to use machinery wherever we can get the same or better results. Man labor and horse labor are scarce and expensive during the summer season in the country districts.



Hand Loading of Road Material From the Stock Piles.

A steady supply of material is not always available, so that we stock up such material as we can obtain. Wayne County is particularly poor in good road material and everything is shipped in. We are using washed and screened gravel, and washed and screened sand. The gravel ranges in size from $\frac{1}{4}$ in. to $1\frac{1}{2}$ in., and the sand from $\frac{1}{8}$ in. down to dust. We use cement in the proportion of one part cement to three parts of stone and sufficient sand to fill the voids. Wherever we can, we stock the material at convenient points along the roadside and rehandle it during the coming season. We find that we can rehandle it with a clam shell and with a Brown hoist cheaper than we can stand for delays during the working season. Our season is short, and we have to do a large amount of work in a short space of time. With a gang of thirty-four men,—including the foreman, the man who runs the mixer, the man who sprinkles the subgrade and the finished concrete to cure it, the two

men who cover up the concrete to prevent its drying out, the fireman, the floaters, and all laborers,—we build, under ordinary circumstances in a day, 550 lin. ft. of concrete roadway 16 ft. wide and 7 in. thick at the sides, with a $\frac{1}{4}$ in. to the foot crown. This we consider a good day's work.

We have to use a combination of hauling engines and hauling equipment, with the horse drawn vehicles. The hauling equipment over unimproved roads is not practical in wet weather, but in dry weather it is a practical and profitable proposition. We haul two or three wagons in a train as a general rule, depending upon the condition of the road over which we are hauling. In some cases the subgrade is so bad that all we can haul with an engine is one



Part of County Road Outfit Starting Out in the Spring for Work.

wagon. That wagon contains seven tons and it will make as many trips in a day as a good team. Under exceptionally favorable conditions we have unloaded, with six men and an unloading device, as many as 25 cars in a day,—not often, however.

The better care and the better attention given to the subgrade, the better the final result will be. We prepare our subgrade flat, rolling it hard, and level. In order that it may not draw any moisture from the concrete, we sprinkle it thoroughly before placing the concrete. Of course, on the sandy subsoil there are less difficulties from cracking than on clay. We lay concrete right on the clay subsoil, just the same as on the sandy subsoil. With the material stocked along

the side of the road, and with the type of mixer that we are using, we can work and unload our material close to the mixer.

The mixer is a very economical device. It has a boom 20 ft. long which projects from the front end, and swings in the arc of a semi-circle. The bucket conveying the concrete from the mixer moves out under its own power on the boom.

Our mixture is a rich one—1:1½:3. We have tried 1:3:5, 1:2:4, and 1:2:3, but experience has taught us that with the 1:1½:3 mixture we obtain the best results. We believe in thoroughly mixing our concrete, and use a wet mixture. We grade our materials so as to make the finished product as dense as possible.

We put down 2 in. by 7 in. side rails, and the templet is drawn back and forth to give the road its initial shape. The final finishing is done with wooden floats. The men work from a bridge. After the concrete is once in place, no one is permitted to step in



Concrete Mixer with Swinging Boom for Delivery Across the Roadway.

it or throw anything on it, as that forms depressions or ridges. That would be cause for instant dismissal of the offender.

We sprinkle the concrete for eight days and cover it with loam, sand, or any convenient material, to a depth of 2 or 3 in. to keep it from drying out.

Last summer the adjacent county built an asphalt macadam road at a considerable higher price per square yard than our road cost. On the seventeenth day of August this road was opened for traffic. On the first day of November I went over the road and counted 137 holes in the first mile, counting nothing as a hole that was less than a foot square. This will give you an idea of the amount of traffic. I do not mean to intimate that it was a poorly constructed road; simply that it will not stand the traffic that it is called upon to carry.

Our roads are not only good automobile and horse-driven



Shaping the Road Way with a Templet Working on the Side Rails.



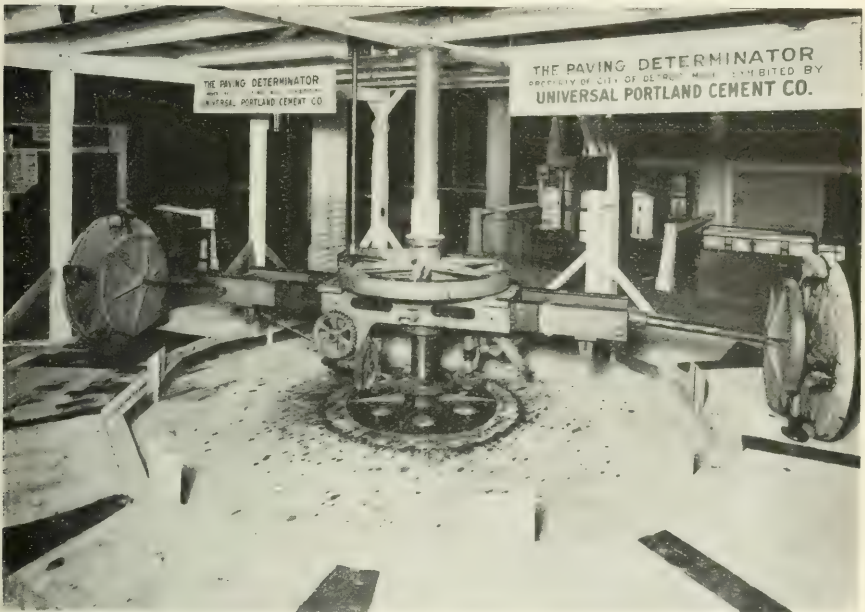
Finishing the Surface of a Concrete Roadway.

roads, but are good for bicycles, roller skates, marble playing, and many other purposes.

On the maintenance feature especially the concrete road excels others. With over 60 miles of road, some of it in its fourth year, some in its third year, and some in its second year, we have not spent \$300.00 for surface maintenance,—not on a mile but on all of it, and not in one year but from the time we laid the first mile until the present time.

Every test to which the concrete roads have been subjected only emphasizes their good points.

In the city of Detroit last year there was a great deal of discussion occasioned by the deterioration of the pavements. An in-



Paving Determinator as Exhibited at the Concrete Show in Chicago.

vestigation committee was appointed, with the Board of Commerce taking the initiative. The Common Council voted an appropriation and placed it in charge of Boiler Inspector McCabe, who designed an ingenious machine whereby the conditions of actual wear by traffic may be approximated as closely as possible.

The "paving determinator" used in this test, was designed by the Board of Public Works, City of Detroit, Michigan, and reproduces, though greatly accelerated, the wear and tear on pavements occasioned by heavy horse-drawn vehicle traffic.

The machine consists of a central vertical column or pivot, about which revolves a horizontal shaft having heavy, solid metal

wheels on each end. The wheels are 48 in. in diameter, have 3 in. tires, and weigh 1400 lb. each. While the wheels remain at a constant distance apart with respect to each other, as they move around the central pivot the radius of one increases and that of the other decreases, so the surface traveled is subjected not only to rolling friction but also to heavy abrasion caused by the constant shifting in and out of the wheels.

To reproduce the wear due to rough shod horses, each wheel is provided with five plungers, on the ends of which are metal plates shaped like the bottom of a horse's hoof, each plate having four steel points similar to horseshoe caulks. As the wheels revolve, these plates strike the surface traveled a heavy blow, regulated by means of a cam gear and springs.

The greatest wheel radius of the machine is 10 ft. 10 in. The least radius of travel of the inside edge of the wheel is 8 ft. 7 in. and it requires approximately 330 complete revolutions for a wheel to shift from the inside to the outside of the circular ring 27 in. wide that it travels.

A test was made at 9 revolutions per minute about the circle, which gave a travel of 6.96 miles per hour, while the wheel speed, when traveling on the inner circle, was 5.51 miles per hour. The desirability of uniform speed on the inner circle was considered, but it was deemed best to provide for the variable speed in order to study the effect of this difference on the actual wear.

The first test made was on various types of pavements consisting of cedar block, creosoted block, granite, four kinds of brick, and concrete. An 8 in. concrete foundation was prepared, and the cedar block, the granite, the creosoted block and the four different kinds of brick were laid on this foundation with a 2 in. sand cushion. There was also a section of concrete 6 in. deep built according to the Wayne County specifications. The first thing that went to pieces was the granite block, strange to say. The grouting gave way and a wear of over 1 in. took place. One section of the brick wore so badly that it had to be removed entirely, because the mechanism of the machine could not get over that section. Other sections of the brick wore from 1 in. to 3 in., and not only to that extent but irregularly and in patches. The wear on the concrete was almost imperceptible, and it stood up the best of any of the materials that were tested. The next best material was the creosoted block, which in our locality costs about three times as much as the concrete.

The Wayne County Road Commissioners, in the work that they have done, have demonstrated (at least to their satisfaction) that concrete is a practical form of road construction. They do not come to you with anything to sell; they do not control any processes or any patents. It is purely a question of fact and not of opinion. These concrete roads are there and they are either good or not good. We do not say that concrete is a panacea for all road

ills, but we believe that it is a practical and economical form of construction, worthy of receiving consideration, not only for country roads, but for residence streets in cities and villages.

DISCUSSION.

Langdon Pearse, M. W. S. E. (Chairman): I would suggest that Mr. Hines tell us something about the cost, and also the effect of such a pavement on horses' hoofs. I refer to this because at one time the question of designing municipal stables came up, and the stable men say concrete is injurious to horses' hoofs, where they have to stand on it.

Mr. Hines: The question of cost, as I see it, is largely a local one. I think that in the building of the roads too much consideration has been paid to the man who attempted to build the greatest amount of yardage for the least amount of money, forgetting that cost is an annual affair rather than a first affair. We have built concrete roads in Wayne County as low as \$1.04 per sq. yd., figuring in the drainage, the engineering, the culverts, subgrading, and grading,—all those things,—figuring on the concrete yardage only; and we have built them at a cost as high as \$1.71. The conditions on a given mile of road are not necessarily the same as on some other mile. We pay \$1.00 per ton for washed and screened gravel. The lowest price that we have paid for washed and screened sand is 83c per ton. We have paid as high as \$1.85 per ton for gravel, and \$1.55 per ton for sand. We cannot approximate costs under such conditions. We have hauled as short distances as half a mile and as long distances as nine miles. The question of cost is something that must be settled in individual communities. I think our cost has been, on an average, about \$1.50 per sq. yd. I do not think we shall ever be able to build at as low a cost as \$1.04 again, and I think under ordinary conditions we shall not have to pay as high as \$1.75 per sq. yd. We have an efficient organization and are putting all the money necessary (not with the idea of being wasteful) into making a good road, a durable road, and a road easily and cheaply maintained.

I think the question of maintenance on concrete roads is worthy of more attention. When we reflect that less than \$300.00 has been spent for surface maintenance on nearly 65 miles of road, it is a striking contrast to what is being spent for maintenance in other sections of the country. I do not want you to infer that we are allowing our roads to deteriorate, for we are not. They are being maintained in a first-class condition.

In New York state last year, they show through their reports (if I am able to figure out what their reports mean) that they spent on an average of \$1010.00 per mile per year for maintenance. The Massachusetts state report shows that on 243 miles of bituminous macadam road in 1911 they spent an average of \$1,293.00 per mile for maintenance.

It will not take many years, with the freedom from maintenance which our roads have had up to date, to overcome a big handicap, and, in fact, to be able to tear them up and replace them.

On Grand River Road we built two miles of tar macadam roadway. It was built as well as the engineering skill and the art of the road builder could do it, but we had hardly finished the work before we had to go back and repair it. In the last six years it has been re-surfaced five times.

Knowing what I do today, if anybody should come to me and say, "We will build you two miles of tar macadam road and not charge you a penny," stipulating only that the road should be properly maintained, it would be more economical for us to reject the offer and build a concrete road at a cost of \$12,000 to \$13,000 per mile. In eight years we would be money ahead.

With reference to the question of horses' feet, many people from all sections of the country come to Wayne County to see what we are doing, and that question is one of the first asked. I simply say to the gentlemen who are going out to look over the work, "Don't ask me; I don't know anything about it; ask these teamsters." The average teamster or farmer will say concrete pavement is not hard on the horses' feet. Occasionally one will say it is hard on the horses' shoes, but it is easy on his shoulders, because he can pull the load with half the effort. I think that it may be hard on the horses' shoes, but no harder than the granite block. When they talk about the resiliency of granite block as compared with concrete, I cannot quite see it.

J. Bement, M. W. S. E.: It seems to me that the maintenance cost of \$300.00 spread over such a large mileage of concrete roadways in the time involved, is a very small sum per mile per annum. It is therefore a question, in my mind, whether any maintenance whatever should be charged, especially so in view of the fact that it is my understanding that this sum was expended in the correction of minor faults which developed in the earlier work, such as repairing of certain cracks. If this is true, it appears to me that the depreciation, if any, which has occurred, has been too small up to the present time, to take account of. This remark is not intended as a criticism of the author's presentation, but to call attention to the fact that upon the basis of the presentation of the subject, it will be more nearly correct to say that there has been no maintenance whatever during the period in which the pavement has been in use.

(The following questions were asked of Mr. Hines by the members and guests, to which he responded:)

Q. May I ask, Mr. Hines, what you figured, in your maintenance costs?

A. In speaking of our maintenance charges on the concrete road, I refer to the concrete surface only.

Q. Did you provide any of the drainage area with clay road?

A. We are handicapped on the drainage proposition, from the fact that the drainage areas do not restrict themselves to township or county boundaries. We believe we could get better drainage if we could reorganize these conditions, not only in Wayne County, but in adjoining counties; but we cannot do this and so we manage the best we can under the circumstances. Here and there we are able to carry drainage to its logical outlet and then we go down deeper than where we are handicapped by the fact that in the next township conditions are different.

Q. That is not answering the question. Should you not have additional drainage with a heavy clay soil? The soil is mostly sand, isn't it?

A. It is mostly clay.

Q. Is it as heavy as Wisconsin clay?

A. I don't know much about Wisconsin clay, but clay, of course, is not an easily-drained subsoil, and wherever we can we give it all the drainage possible.

Q. Do you not give it additional drainage, except the side ditches?

A. No. Where we have street-car tracks along the side of the road we are laying 4 in. land-tile.

Q. The \$300.00 per year for 65 miles is just for surface maintenance then?

A. Yes, and it does not include cleaning out ditches or cutting weeds.

Q. I am interested in the repair of the pavements in case there are worn places in the concrete surface.

A. We have not yet had any worn places, but we expect we shall have, eventually. When that time arrives the concrete can be used as a foundation either for a very thin bituminous coating or for some thicker coating of asphalt, brick, or any other surfacing material that may be evolved in the future.

Q. Do you find any need for expansion joints in the work?

A. Yes, we do. We are making a $\frac{1}{4}$ in. joint, with asphalted felt cutting clear through the concrete and protected on the edges by Baker armor plates. We make these every 25 ft. but that is purely an arbitrary distance. It is possible that the joints could be carried farther apart, but our results have been so satisfactory and the saving of taking out a few of those joints is so slight that we have not deemed it desirable or advisable to go ahead and experiment. Of course, we are not running an experiment station, and if the Government evolves a distance of 30 or 40 ft. that proves as good as ours in practice, we will adopt it.

Q. In this last year we constructed about a mile of concrete road 16 ft. wide. On account of a limited amount of money, we did not provide iron-bound joints, and we all regret it. We would not construct any pavement of this kind now without iron-bound joints.

A. In the first year or two of our experience, we experimented with several forms of joints, namely a Georgia pine board; tar paper; an angle iron. We tried dividing it and putting in a composition of pitch and asphalt, and various other plans that we thought would prove practical. We found there was a tendency on part of the concrete to spall at the joints. We have stopped that spalling by filling the joints with a heated tar and coarse sand, spreading it two or three inches each side of the joint; it prevents further wear, protects the road, and makes a nice even, level surface. We feel, with the experience we have had, that the only place that we are looking for improvement now is in the leveling up of our road so that there will be no ridges or depressions. We want a road that you can squint along for two miles and knock a fly off with a rifle bullet.

Q. Do you not find that with the steel plates you have a rough joint? That is, does not the road, the surface proper, wear down faster than the steel joint?

A. Neither one of them has worn as yet.

Q. Will not that be the case later?

A. I think not. This is a soft steel plate, and I think if there is any particular wear there in the future, the steel will wear with the rest of the road. We have had that kind of plate in use three years now and the wear seems to have been the same on the road as on the steel.

Q. In case there is a very soft place in the clay, and you cannot roll it, do you put the concrete on regardless of that?

A. Yes, we have done that.

Q. Do you make the concrete any thicker or do you reinforce it?

A. We have not done any reinforcing except on a few experimental sections. Here and there the concrete has been made thicker, but I do not advocate that, because I believe cracks will develop where this practice is followed. Where we have had soft spots of any size, we have dug them out and filled them with stone. In the case of small ones we build over them.

Q. Do you work only when conditions are proper to make the subgrade?

A. Yes. We have a large amount of work to do and we get started as early in the season as we can; while it is more expensive to prepare the subgrade in wet weather, yet it can be prepared in a suitable manner by building the side ditches and making some provision to take the surface water off before the concrete is laid.

Q. Do you do any work in freezing weather?

A. We have done some, but our hearts stood still all the time we were doing it.

Q. The part of the country I came from,—Minneapolis, Minnesota, and North Dakota,—the frost penetrates the ground some 8 to 10 ft. during the winter. With proper drainage on the

side, do you have any trouble with the concrete or earth caving in so as to affect the concrete?

A. Last winter was a severe one in Wayne County; the frost went down 5 or 6 ft. and it did not affect our roads at all.

If I should say that everything we had done was A1, it would insult your intelligence, because it is not A1. We have made some mistakes, lots of them, but we have not made the same mistake twice. When we started out, we contracted our jobs and went into competition with the contractor where conditions were similar; we are now doing all our work under the day-labor plan, believing it to be more satisfactory. Our first work does not begin to typify the work we are doing today. The work we are doing today is very much better. Here and there a section has been heaved by the frost or other causes, but I think over the 63, 64, or 65 miles there are not more than a half dozen sections which have heaved up perhaps an inch. I presume it is possible to eliminate all such conditions. It is necessary to take the practical cost of the proposition as well as the theoretical.

Q. Has the heaving been more pronounced on the clay than on the sand road?

A. It has been largely on the clay.

Q. In Minnesota and Wisconsin most of the roads are sand.

A. They ought to make ideal roads for building concrete.

Q. A few moments ago you mentioned the development of certain cracks. To what cause do you attribute those cracks, have they appeared on the later roads, and is it important to eliminate them?

A. The first mile we built was on Woodward Avenue, and we built that with what, for want of a better name, I would call an inverted curb. We had a curb going down some 4 or 5 in. We had an idea that this was going to be quite a "nifty" thing. I do not remember now what the idea was, but the tendency due to expansion and contraction from heat and cold and from moisture was to present a resistance there that it could not overcome, and it just pulled it apart in the middle. More cracks have developed on that one mile than on any other subsequent 15 miles outside of the first two miles on Michigan Avenue. On the first two miles on the Michigan Avenue road, the cracks are entirely due to a very, very poor foundation. Michigan Avenue, when we took it over as a country road, did not exceed 15 ft. in width, measuring from the street-car tracks, and we widened it to at least 24 ft. We made that fill and built on it in some cases two weeks after it was made. It is not surprising that we developed a great many cracks. On the work we did last summer, of course, I do not know how many cracks will develop, but the work done summer before last did not develop more than three or four cracks to the mile, which is a negligible quantity.

Q. I would like to ask what the attitude of the taxpayers has been, that is, the property owners?

A. The taxpayer says, "When are you coming our way? Our road has the most traffic of any road in Wayne County. You ought to come out here, because it is the most important road in the county." After we started to build concrete roads, the people of Wayne County said we were not going fast enough, we were not building enough miles, and they wanted to bond the county for \$2,000,000 to be spent in one year. We had to fight that proposition. The people said, "What kind of a bunch is this? They fight for these roads. Then we want to give them \$2,000,000 and they turn around and will not take it." I recall an editorial in one of the papers. I had said we had not developed the organization to spend any such sum of money and the newspaper said, in substance, "We went over this road yesterday and it looked just as good as the day it was put down. This man doesn't know what he is talking about."

We finally compromised on the basis of extending this expenditure over a period of five years. There is great demand from every corner of the county to "come out our way."

Q. Have you constructed any curb in conjunction with your paving proper?

A. We have not. On Jefferson Avenue the village of Grosse Point Farms has since constructed a curb.

Q. You mentioned 18 ft. What has been decided on as an ideal width for concrete roadways in Wayne County, including shoulders, for the road?

A. We have made a definite plan covering a period of years and have largely, in our own minds at least, decided in which direction we are going and have divided our roads into three classes: First, the trunk roads, which are the main leading roads into the city of Detroit. On these we have determined a width of concrete of 16 ft. with a minimum width over all, including the shoulders, of 24 ft. The shoulders we are building of limestone or gravel, depending upon the respective availability of the material. Second, the lesser traveled roads. We term these our secondary roads, and connect up the smaller centers of population one with another. We have laid them out largely with a width of 15 ft. of concrete, 24 ft. over all. Third, the subsidiary roads. We are putting these down 12 ft. of metal and 24 ft. over all, with gravel and limestone shoulders, bringing the metal of the concrete 12 ft. and 3 additional feet on each side of limestone or gravel, and the balance earth.

Q. Do you consider the 16 ft. road wide enough for automobiles going in opposite directions at a fairly good speed, 25 or 30 miles an hour?

A. That has been our experience, and with good limestone and gravel shoulders there is plenty of turn-out room. With 24 ft. over all and 16 ft. metal, it is a good, safe, two-track road.

Q. Have you ever noticed two loads of hay passing one another on a 16 ft. roadway?

A. I don't know whether the gentleman is "kidding" me or not, but Detroit ships very little hay to farmers. One of the problems, when we first start, is how two loads of hay are going to pass each other on our roads. For instance, on Michigan Avenue, which at its widest point was only 16 ft., the two mythical loads of hay got by each other, and yet on the 24 ft. road which we have put there, the two mythical loads are having a bad time.

Q. We have a drainage proposition in Walton County, and the court prevented us from opening it up. The result was it went into winter quarters with ice on the ground. What will happen to that in the winter? Do you grade as you go along, and how heavy a grading do you have?

A. With reference to the first question I cannot say, but I will be very much surprised if you do not develop quite a few cracks where your drainage is not properly taken care of. We grade ahead of our work as far as we can. We are in a valley and our country is flat, but the ordinary unimproved road follows the contour of the country up hill and down, not any very steep grades. The steepest grade on which we have laid concrete is a 4% grade. The further ahead of the work the grading is done, the better the subgrade, and the better the subgrade the better the road.

Q. How deep a fill do you put in?

A. We have had two exceptional cases where we filled 15 ft. But there is a foot here, two feet there, and a foot and a half, and three feet and a few inches. It is hard to suggest to you any average.

Q. Do you put concrete right on that fill?

A. Yes, right on the fill.

Q. If you had a fill 15 ft. that ran off 150 ft., would you put concrete on that the same year?

A. No, I would not put it on until the next year.

Q. Doesn't concrete crack more in clay soil than in sand?

A. With the later work there has been very little cracking in either the clay or the sand. My idea is, based on experience, that without careful preparation of subgrade we would have more cracks on the clay than on sand. A sand subgrade does not need the same careful preparation as a clay subgrade, to put it the other way.

Q. What is your opinion of the shape of the subgrade,—the way it ought to be?

A. We make it flat. We believe a flat subgrade has a tendency to overcome frictional resistance and thereby decreases the development of cracks.

Q. Will you tell us of your experience with aggregate, and so forth?

A. Our first work was two-course work. The wearing surface was made with a very large aggregate,—not because we believed in a large aggregate, but because we had it at the roadside. We had intended building a macadam road, and when we saw how our

other macadam roads were wearing we felt it was uneconomical to haul it away and we used it. The surface consists of crushed cobble-stones 1 in. to 3 in., and it is too big. We now try to grade the stones to reduce the voids to a minimum. We aim to get the stones rather than the sand, to the top. The function of the sand, of course, is to fill the voids in the stone, and the function of the cement is to fill the voids in the sand and supply the bond. That is one reason we are so careful to keep the men off the concrete when it has once been placed. If they stamp on it they bring the neat cement and sand to the top.

Q. Will you tell something about the one-course work?

A. We are now using one-course work entirely. We found, with our two-course work, that while the material itself was cheaper, the additional labor and the additional care we had to put on it made it about the same price, and we believe if it is one class of material all the way through it is better quality.

Q. How do you tamp your concrete?

A. We do not tamp it.

Q. How do you get the air out of it?

A. With the handling it gets in dumping and in scraping over it with the templet, I think there is very little air in it.

Q. Have you had conditions where you had to use reinforcing material?

A. I do not advocate the reinforcement of a concrete road under 20 ft. If you get above that, it is better to reinforce it. I think occasional cracks, even if one has to tear out a whole section, are more economical than spending 10c or 12c per yd. additional for reinforcement. We put down two or three sections reinforced with the joints 50 ft. apart, purely as an experiment; we have not paid much attention to the result of the experiment.

Q. There is a peculiar condition in Minnesota, near Lake Minnetonka,—a sort of pocket that continually sinks. It is probably a quarter of a mile long. For 20 years the county commissioners have filled it up with rock, sand and dirt of all kinds, but they have never been able to put anything down there that would stand up. Now they are figuring on putting a concrete road over that bog.

A. I believe I would use reinforcement if I were doing the work.

Q. Have you had any trouble with so-called blowouts?

A. No. Our pavement is 7 in. minimum thickness. We are going to cut it down a little this year. Of course, we are right next to a big city and our roads carry a tremendous traffic. Take, for instance, the traffic of a street 100 ft. wide, and a continuation of the leading main paved retail street of a city of 600,000 inhabitants. The traffic, when it gets on to our country roads, is centered on 18 ft. of concrete, and we thought we would better err a little to the side of safety instead of seeing on just how thin ice we could skim over. We have gone a little to the extreme as to

thickness, and I do not believe it is necessary to build to as great thickness as we have. We are going to cut down to 6 in. at the side on a flat subgrade with a $\frac{1}{4}$ in. crown, which will make it about 8 in. in the middle.

Q. How many miles does your program for 1913 include?

A. We are going to build all the mileage for which we can get materials, and we feel that we will have more money than we can build mileage, because of scarcity of material. I might state, in that connection, that we are not going to build anything but concrete in 1913.

Q. I am interested in the question of expansion joints. You were saying that you believed they were absolutely necessary. What experiments were made to determine that and the spacing finally adopted?

A. The spacing we finally adopted was simply an arbitrary distance.

Q. Opinions differ all over the country on the question of expansion joints on concrete roads. I have built some roads which did not have any. We let the cracks come where they would, and I cannot see that they are any the worse.

A. I believe it is better to have the cracks at regular intervals rather than in a haphazard way, and that it is better to have them protected than not protected.

Q. Yes, if you have them it is better to have them protected; but I was wondering if you had run any long stretches to see what would happen.

A. The detail of construction is based on observation of sidewalks and other concrete work. We tried to stay on the safe side and have erred to the side of safety as far as possible. It is no light matter to spend five or six hundred thousand dollars of somebody else's money and live in the community afterwards. Mr. Butler, Mr. Haggerty and I do not make a living by putting in concrete roads or any other kind of roads in Wayne County. We get \$5.00 per day, and I do not think any one would consider that we are overpaid. We have other business interests from which we earn a livelihood and we want to continue with those other interests.

You will realize that these details are processes of development. They did not all come in a minute. What one man did not think of, some other man did, and that has been one feature of the work. I do not mean the commissioners, I mean the man that worked the cement, the man that pushed the wheelbarrow, and the man that ran the level,—it is the pride our men take in the work.

When Mr. Haggerty ran for office two years ago, he did not print an advertisement, circulate a card, or make a speech, and he was overwhelmingly elected. The same thing was repeated at the last election when Mr. Butler and I were elected; we did not print an advertisement, circulate a card, or make any speeches. The county went Democratic on the Governor, and "Bull Moose" on

the President, and we were elected on the Republican county ticket by good majorities. We believed the best political advertising we could get was a permanent, durable road, and this has proven to be a fact. Our men have been imbued with that spirit. They are trying to give Wayne County a dollar's worth of value for a dollar in money. No man is employed because of political affiliation or political leaning. We have Hungarians, Bulgarians, and Italians, men who are not even citizens. The crew on the Michigan Avenue road was almost exclusively young men working their way through college. It was tough "sledding" for a few days handling those big wheelbarrows, but when they got used to it they did good work and a lot of it.

The work is of sufficient magnitude so that we can specialize. We put one crew on grading, one crew on concrete work, one crew on culvert work, one crew digging ditches, and so on. In that way we get more efficient service than if we attempted to use the same men on a number of different tasks.

Q. Where did you get water, along the line?

A. That is another one of the little economies we have worked out. For instance, on a section of the Grand River Road the nearest available supply of water was six miles away. We laid a 2 in. pipe and used three gasoline engines to pump water to the work.

Q. How smooth is the surface?

A. We finish the surface with what looks like a very smooth coat, but, as a matter of fact, it is very gritty. It is not slippery in wet weather, unless the weather is cold enough to freeze; a coating of ice is slippery. When the pavement is wet it is not as slippery as creosoted block or asphalt, and compares favorably with brick.

F. P. Wilson (City Engineer, Mason City, Iowa): I have been much interested this evening in Mr. Hines' talk, and the conclusion I have drawn is that he has put Wayne County on the map for country highways. In the past four or five years I have been in like occupation, trying to put the good old state of Iowa (especially Mason City) on the map, by constructing some of the best concrete pavements for city streets that can be found in the United States. In the past six or seven years I have made extensive investigations of concrete pavement for city streets, for roadways where there is light traffic, and for roadways where there is heavy traffic. I think a concrete pavement constructed with a good set of specifications, good cement, good clean sand, good hard stone, expansion joints at proper intervals, the sides of the expansion joints protected by softened steel protection plates, the subgrade kept thoroughly dampened in the course of construction, the pavement after being completed being kept thoroughly wet at least ten days, certainly warrants its use on city streets on account of its first cost, cheapness to maintain, and the cleanliness of the streets.

In 1909 Mason City constructed 10,000 sq. yd. of cement pave-

ment in the downtown district, where it would receive the heaviest traffic. At the present time, after standing the severe tests of the past two winters, it is in as good condition as the day it was put in. In 1910 Mason City constructed 25,000 sq. yd. of cement pavement, both on residence and business streets. In 1911 50,000 sq. yd. were constructed. During the past year 52,000 sq. yd. were constructed, both in business and residence districts, at a cost of \$1.08 per sq. yd., which includes the cost of excavating to a depth of 7 in., and the construction of a two-course concrete pavement of a total thickness of 7 in. The reason the two-course pavement was adopted in Mason City was on account of the softness of the limestone aggregate. The base of the concrete pavement consisted of one part of cement by measure, two parts of sand by measure, and five parts of crushed rock, the rock being crushed so that the largest fragments would pass through a $1\frac{1}{2}$ in. ring. Immediately upon this base was placed a wearing surface 2 in. in thickness, consisting of one part of cement and two parts of screened sand. The sand we used in Mason City is shown, by analysis, to contain 80% granite. In constructing this pavement we first laid down 25 in. of concrete, and immediately on top of that was placed the wearing surface. The expansion joints were placed $37\frac{1}{2}$ ft. apart at right angles with the curbs, with blind or contraction joints every $12\frac{1}{2}$ ft., and steel reinforcement plates on each side of the expansion joints. These plates are practically the same as the Baker plate used by Mr. Hines.

The street pavements in the residence district are constructed 30 ft. in width between curbs. In the business district some streets are paved 47 ft. in width between curbs. On several streets in the downtown district there are street-car tracks. We pave the tracks with concrete just the same as if they were not there. We excavate a trench 14 in. in depth and 7 ft. in width, which is thoroughly rolled and compacted with a 9-ton roller. Then the rails and ties are placed in position. We use one part of cement, two parts of sand, and four parts of crushed rock,—an extremely wet mixture. This mixture is run in just the same as a floor-beam or column would be placed in a concrete structure or building. The ties are placed 30 in. centers. Immediately after the concrete is placed we put a wearing surface of $2\frac{1}{4}$ in. in thickness of one part of cement and two parts of screened sand. We have a machine that cuts out a shape similar to nose brick for brick construction. We save \$1.10 per sq. yd. between this class of construction and the same class of construction with a first class paving brick. At the end of the ties we have a blind joint, so that the pavement proper is separate from the street-car track construction.

During the past two years we have constructed in the neighborhood of 2000 ft. of street-car track with cement concrete paving at \$1.75 per sq. yd., and when I came away assistants in my office were making plans for 60,000 sq. yd. of cement paving, a contract for which I expect will be let the middle of next month.

March, 1913

I visited Sioux Falls, South Dakota, this week, where plans are being made for ten miles of cement paving, or about 200,000 sq. yd., a contract for which will be let in the near future.

F. E. Davidson, M. W. S. E.: About eight years ago some concrete pavement was laid, under my direction, on 48th Avenue between 22nd Street and Ogden Avenue, adjacent to the plant of the Western Electric Company at Hawthorne, Illinois. The equivalent of three-quarters of a mile of pavement was also laid inside of the plant. Some of it was laid ten years ago, some nine years ago, and some seven years ago. The construction was a 7 in. base of a 1:3:4 mixture of cement, torpedo sand, and stone, with a 2 in. top finish of a 1:2 mixture of cement and granite screenings. It was ruled off in brick squares. I saw the pavement about three weeks ago, and the wear in most places is hardly appreciable. Personally, I think that for medium weight traffic there is no pavement known today that is so satisfactory, so cleanly, so easy to repair, and so cheap as this form. The cost of the work was \$1.80 per sq. yd. That included the preparation of the subgrade and the complete finish.

Mr. Hines: I think it is safer for a while to let the pavement demonstrate itself on country roads and medium traffic streets rather than court failures and kill the proposition. To me it seems like a commercial and an economical proposition. I can judge from the number of people who, through various influences, have come to Wayne County for information. If they were satisfied with the cost and the durability of the type of streets and roads that they had been building, they would not come 10 to 10,000 miles to see what we are doing in Wayne County. There are three things which most people think they can do better than anybody else,—build a road, run a newspaper, and conduct a hotel. Until the general run of contractors, and others interested in paving matters, get away from the idea that the addition of a little cement and some water to some sand and stone makes concrete, I think it is safer to advocate the use of concrete pavement on streets of medium traffic and country roads, and when it proves its worth there, as I believe it will if properly constructed, then it is time to invade the heavy traffic streets.

I cannot see the object of putting cracks in the concrete. They simply gather dirt and thus cause more wear. The fewer the obstructions on a road of any type, the less wear there must necessarily be upon it, because with a wheel rolling smoothly over the road you do not get a drop. Even a small drop with a heavy load is bound to create a weak spot and an abrasion. I cannot understand why one should go to the expense of corrugating, because the pavement is not slippery. That is the only excuse I can see for corrugations.

Mr. Davidson: I want to add my observation on that class of work. I would never use anything but granite screenings or quartzite. I believe, with the speaker, in advocating a wet mixture

for this class of work, but I should always use granite. I would not trust crushed stone or ordinary sand unless it contained a large percentage of granite.

A Guest: I have constructed concrete pavements on a city street where the grade was over 9% with a rough cut finish without any corrugation. Another street had a 5½% grade without corrugation,—just a rough flow finish. It was not as slippery as the adjoining street, a brick street of similar character, and adjacent to that was a creosoted block street where the horses could not stand at all.

Q. What do you think of oiling a concrete surface?

Mr. Hines: It is an unnecessary expense on our road, because the function of the oil, as I understand it, is to lay the dust, and we have no dust.

J. S. McCullough (City Engineer, Fond du Lac, Wis.): I am glad to be here tonight to listen to the experience of others. This type of construction was started at Fond du Lac in 1908. The first season's work amounted to about 30,000 yd. and each year since that time we have added to it, until we now have in the aggregate 140,000 sq. yd. of concrete. We started out by building plain concrete streets, using a local gravel and crushed stone. After the second season I concluded that our local gravel contained more clay than was beneficial, and for the last two years we have been shipping sand in from a pit about 40 miles from Fond du Lac and combining that with crushed limestone for a base. In the top we used equal parts of sand, granite, and cement, making a mixture that is one part cement, one part sand, and one part granite.

You may not agree with me, but I have an idea that by mixing the granite and the sand in equal parts the mixture is more gritty than with all granite. That is, after any wear takes place, I think with all sand the wear will be greater than if part of the top course is of granite, and with all granite in the top the surface will become more slippery. I think there is an opportunity to watch the difference in wear on the surface in the difference in the size of the aggregate. I know that Mr. Hines uses larger aggregate or the same size all the way through, and some of our neighboring cities in Wisconsin have been using up to ¾ in. granite in this top course with sand. Our granite is what is known in the market as Wisconsin Granite Company's No. 5. It runs from ¼ in. down to the finest with the dust out.

For the past three seasons we have reinforced pavement slabs with American Steel & Wire Company's mesh, on account of development of cracks, which I attribute to the friction on the base and the concrete changing volume by heat and cold. The cracks have been very materially reduced in number, but have not been entirely eliminated; they do not open up, and if a crack does not open up it does not get a chance to ravel. On the oldest pavements we filled the cracks with asphalt and sand, similar to the method of Mr. Hines.

Mr. Hines: Does the asphalt stay in?

Mr. McCullough: It does if the crack is large enough to get it in.

Mr. Hines: We find the tar sticks better than the asphalt.

Mr. McCullough: I believe it would. The reason we used asphalt was because we had been using it to fill expansion joints.

There is one point about our work that I think could be improved upon, and that is, I think we have been making the joints we leave for expansion, wider than necessary. We have been specifying a space 1 in. wide every 50 ft., and if we reduced that by half its width I think it would be ample.

Mr. Hines: I think you are safe in reducing it to $\frac{1}{4}$ in.

The shrinkage of the concrete drying out, then the expansion that comes on it through the further expansion of moisture or heat and cold, which is very little, more than equalizes the shrinkage in the first place.

I might tell you how we came to use tar instead of asphalt. We tried the asphalt and found it did not stick well; then we used tar because there was a creosoted block pavement that abutted right up to our concrete on Woodward Avenue, and about an inch of tar "boiled" out. It dropped off on to our concrete, making the concrete unsightly. I took some men out there one day and said, "We want to clean this off." They got some scrapers and picks and one thing and another, and when I returned they were working on the first 25 ft. I said, "Let me show you." I worked half an hour and had moved a piece about as big as a dollar. So I concluded if it would stick that way without any preparation and without any cleaning off, it would stick well if we cleaned it off and made some preparation for it. Results have justified that conjecture.

Mr. McCullough: One of the remarks generally made in reference to concrete pavement is, "It must be difficult to cut through it." We have had more or less trouble along one of our paved streets where there is a street-car line, and the street-car company manages to cut through it with ordinary chisels for the purpose of renewing broken rails. A year ago the Wisconsin Telephone Company wanted to do some conduit work in Fond du Lac, and they were obliged to cut through several pavements, among them being a long stretch of concrete. They used a steam drill, the same type as is used in stone quarries,—a small drill,—and drilled holes about every 10 in. to 1 ft. apart, alongside the gutter in a straight line, and broke the concrete out in slabs about 6 ft. long with feathers and wedges. We took the slabs out to the park and used them in making a breakwater. The telephone company replaced the concrete with new material, and did not attempt to use the old over again by crushing it. They paid the contractor the price stipulated in the original contract for any trench work that became necessary within the five years of his guaranty, which price was \$1.50 per sq. yd. They paved that and paid for all the filling up of

the trench up to the concrete itself at their own expense. The work was actually put back, I understand, by the original contractor sub-letting it to a local man for about \$1.25 per sq. yd. The telephone company, on the other hand, did some of the work on the brick streets with their own men at day-labor prices, and it cost them two dollars and some odd cents per yard to do the same work; that is, put in the concrete base and lay brick, and they used as many of the old brick as they had not broken in taking them out. There was considerable saving to the telephone company in replacing concrete over replacing brick.

H. J. Kuelling (County Highway Commissioner, Milwaukee County, Wisconsin): Milwaukee County is in its infancy in concrete road construction, and I came here to get pointers from some of my neighbors. The problem I had to face was a county where there were practically no roads except gravel roads. Last year we started with a sum of money amounting to about a quarter of a million dollars, and naturally we could not begin to spend it. I had a crew of men that knew nothing about the business. The first thing we did was to visit Wayne County and inspect the work there; then we patterned as nearly as we could after it, believing there was no necessity for going over the same ground they had.

Conditions in Milwaukee County are somewhat better than in Wayne County. Wisconsin, as you know, is well blessed in materials for concrete, especially certain sections, and Milwaukee County happens to be one of those sections. In some cases, however, the cement has to be hauled long distances, and our roads are not the best in the world.

During the past year we built about six miles of 18 ft. concrete roadway, besides some macadam and bituminous mixtures, but during the coming season we expect to undertake the building of 30 miles of concrete roads. That is a large proposition for a little fellow in the second year of his life, and I do not know whether we can accomplish 30 miles or not. We are going to start off with a rush in the spring, whereas last year we did not have a yard of concrete down until the first of August. We had a new county board with fifteen new members out of nineteen, and there was considerable delay in getting the work started. This year the surveying has been done. Out of the 85,000 yd. of material we have to move, I have already purchased 30,000 or 40,000 yd. I am buying some of my material this year at 10c per cu. yd.

The reason I asked Mr. Hines about grading is this: If we grade very far ahead and a rainy season comes, especially where it is a clay country, our work is delayed. So we aim to keep as close up to the grading line as possible. We have six miles of graded road that was left open for the winter, and if you could hear some of the criticisms we get for leaving that road open, you would not wonder that we try to keep up with the building gang. We have not had as good success as we should have had, for the reason that some joints were not put in as they should have been.

We thought we could save a little money by attempting to select our gravel pits by the analysis of percentage of stone and sand. We made analyses, in a general way, but there are quite a number of errors in our first year's pavement, things I think we can avoid during the coming year by screening all gravel used.

We shall be glad to add our little mite to the concrete road movement, because we believe it is far ahead of the so-called bitulithic pavements. We have tried those to some extent and of the two we prefer the concrete. We have built, during the last season, 30,000 yd. of bitulithic pavement; under it we have placed a 5 in. base of concrete, and I believe it is more economical to add a little more to the concrete and let the concrete take the wear rather than go to additional expense for the 2½ in. binder and the cost of laying.

W. S. Shields, M. W. S. E.: I have recently had the privilege of inspecting a stretch of country road just outside the city of Mattoon, Illinois. It was built under the specifications and direction of Mr. Claude L. James, City Engineer of that city. The road is 9 ft. wide and 6 in. thick, and was constructed at a cost of \$0.76 per sq. yd., exclusive of the preparation of the foundation; ¾ in. expansion joints were placed 50 ft. apart, the edges of which were lined with paving blocks. Each alternate block being laid as headers, gives a toothed effect.

The concrete mixture was 1:2:3, the cement to overfill the voids in sand by 5%, and the mortar to overfill the voids in stone by 10%; the stone varying in size from that passing a 2 in. ring to that rejected by a ¼ in. ring. The concrete was mixed wet enough to flush readily under light tamping, was distributed the full width of the paved portion of the roadway, and was protected from the weather until hardened.

The wearing surface consisted of a dry mixture composed of one part cement, one-half part of sand, and one part of crushed quartz, mixed dry and spread over the surface in sufficient quantity to take up the surplus moisture. The surface was then floated with a wooden floater to a proper form, and irregularities were brought to grade by filling with the wearing coat, which was required to be put in place within 30 minutes after the concrete had been laid.

The road was standing up well under a heavy traffic and was attracting favorable attention.

A Guest: In view of the fact that we have had a little talk on concrete roadways and country roads, I simply wish to state that a little of that work has been done in the city of Chicago. This last year we put in one stretch 30 ft. wide by a little over 600 ft. long; the road is about 6 in. thick throughout, composed of one part of cement to two parts of sand and four parts of gravel passing a 1 in. screen. There are no expansion joints except a ½ in. joint along the vertical concrete curb which we use, and every 12½ ft. we have a contraction joint which approximates 1/16 in. That is to say, we put a thin strip of tar paper at the joint, our idea being

that the concrete, when it is made in warm weather, surely has its maximum expansion at that time and tends to contract during the year in drying out in reduced temperature, and these joints are placed to allow of contraction. On that pavement we put half a gallon of bitumen and about $\frac{1}{4}$ in. of sand, because the pavement was very rough when the contractor, who was a novice, got through with it. It has a very good surface now.

I want to emphasize what Mr. Hines suggested of not going too far into the matter before it is demonstrated. On the street referred to we laid the concrete 2 in. below the finished grade of a finished pavement, with the idea that if the pavement did not prove satisfactory we could put a 2 in. surface of asphalt on it, bituminous macadam, or concrete, and I think pavement could be laid in cities where people are timid about it, with the idea that if it is not a success it can be used as a concrete base.

Mr. Hines: As an experiment, we took a stretch of $1\frac{3}{4}$ miles of one of our first roads (which is not as satisfactory as roads we have since constructed, due to too much clay in the material—it was a screened instead of a washed product), and covered it with Dolorway, so called. We were going to do the work so well that we overdid it, and used a little too much sand and a little too much tar, resulting in the pavement having a tendency to be wavy, the same as in asphalt pavements. We laid two or three short sections on other roads where we cut down the quantity of the tar, and obtained better results. I would advise any one, in attempting to put on a bituminous top, to be careful not to get it too thick, unless they go up to a couple of inches,—just a thin film. If the film is not thick enough it can be increased, but it is difficult to cut it down. If a concrete pavement is built that is a little rough, it can be saved by using it as a foundation, and it will remain there perpetually if it is properly kept up.

RAILROAD BRIDGE DESIGN IN EUROPE AND AMERICA COMPARED

EDWARD GODFREY

Presented February 10, 1913.

The writer was led to look into this subject when he was informed that railroad bridges designed on the European continent are much lighter than American bridges. This was surprising information, when it is considered how frequently the charge is made that Americans generally shave down the design to the last pound.

This paper will be confined largely to a comparison of specifications. The writer hopes that it will bring out facts from members of the Society familiar with European practice, that will explain some of the surprising things that comparison of specifications discloses.

The writer has been under the impression that the increase in train loads and engine loads, so very marked in the last twenty years, has been the outgrowth of railroad development in general and not a thing peculiar to America. It is a matter of surprise to find that modern French specifications were adopted in 1891. Railroad bridge specifications of 1891 would not be thought of in designing a modern American railroad bridge. Railroad bridge designing has made great advances in this country in the last twenty years. The same is true of the loads for which the bridges are designed. Twenty years ago a 123.5 ton engine was considered very heavy for railroad bridges. The axle load of this engine is 35,000 lb. Now Cooper's "E-60 loading" is not uncommon, with axle loads of 60,000 lb. and a combined tender and engine weight of 213 tons. One system uses three 64,000 lb. axle concentrations. Another uses four 66,000 lb. concentrations only 4.5 ft. apart. Another adds a 60,000 lb. concentration to a continuous load of 5,000 lb. per ft.

The specifications of the Prussian state railways give no higher axle loads than 44,000 lb. Those of the French Republic give the same maximum axle loading. The writer is informed, however, that French and Belgian designers use heavier engine loads than these.

The train load following the locomotive in modern American specifications is 5,000 to 6,000 lb. per lin. ft. Both French and Prussian regulations show two axles in the "wagons" with axle loads of 13 metric tons in a length of 6 meters. This is only 2,910 lb. per lin. ft.

A notable difference in European and American regulations concerns tests on finished bridges. In the Prussian regulations much is said of tests, not only upon completion of the bridges but also periodic tests and inspection. The French regulations go minutely into the matter of test trains,—their composition, how they

are placed, the observations to be made both while the train is stationary and while it is moving.

In America, generally, when the ties are laid, scheduled trains pass over the bridge without further ado, if the remainder of the road is completed. The matter of tests has almost entirely disappeared from American specifications for bridges of all kinds. Periodic tests are never mentioned, so far as the writer knows. These matters are left entirely with the Maintenance of Way department of the railroad. Show tests are sometimes made on large bridges for the benefit of the directors, upon completion of the bridge, but these are not taken seriously by engineers.

It is pertinent to observe that while European regulations are prepared and presumably enforced by the respective governments, those in America are prepared and enforced by the several railroads. The latter method might appear to be a poor one, especially where there is so much interchange between the various railroads as there is in America. The bridges on some roads are designed for much heavier loading than on others. When the case is analyzed, however, it is seen that little confusion or danger can arise from the conditions as they exist. It is true that there is a very general interchange of cars on the railroads of America, but the locomotives of one road do not visit on the tracks of another. It is the locomotive loads that govern the size of nearly all of the bridges. The roads provide for their maximum locomotive loading. On nearly all of the roads this is in excess of any ordinary heavy freight car loading.

One system in America specifies heavier loading on a division of the road where the grades are heavier than on the other divisions.

The elasticity that allows a railroad to design its bridges to suit the rolling stock of the road would be difficult to secure under government regulations or specifications. Some roads in new territory seem to find it economical to put in lighter bridges during their period of development, and to replace these as increased traffic demands call for heavier rolling stock and consequently heavier bridges. This is particularly true of girder spans, which in very considerable span lengths can be picked up bodily and placed on cars and hauled to branch lines, or sold to some road in the process of development.

The feature of public safety that government regulation might be supposed to conserve is taken care of in other ways in America. Railroads are held liable for damage due to wrecks or failures on their lines. This makes it incumbent upon them to study the matter of safety of their bridges and design them with these liabilities in view.

A large number of engineering departments are thus constantly studying the matter of safe bridge design, and through engineering societies and publications there is a general interchange of ideas. All of this tends to the perfection of bridge design, especially as it is the American practice to embody these ideas in specifications gov-

erning the design of bridges. This feature will be referred to more fully in a subsequent part of the paper.

There is no doubt sound reason for the European practice of maintaining uniformity in the railroad bridges of the country. Also it must be true that the engine loading used covers the locomotives employed on the roads. The foregoing is not intended as criticism of government regulation in these matters but is merely to show that in railroad development in America it would scarcely work out advantageously.

The surprising difference of 50% in engine loading, and as much as 100% or more in train loading, in some American railroads as compared with European standards, largely explains the statement that was made to the writer, namely, that European bridges are lighter and presumably more economically designed than American bridges.

It is readily seen, by mere comparison of the loading used in Europe with that used in America, that assuming the same unit stresses and the same character of design, there would be a large difference between the weights of European and American bridges, the latter being much heavier than the former.

The matter of periodic inspection has been referred to. This is required and defined in Prussian regulations, whereas in America it is left to the discretion of the Maintenance of Way department. There is perhaps not enough of periodic inspection of bridges in America, but the need of it lies not so much in the fact that bridges wear out as that the loads they are compelled to carry have been constantly increasing. If bridges were designed with an ample factor of safety, there would be scarcely any need of periodic inspection, except for such purposes as to preserve the metal from rust. Rivets that are highly stressed are very apt to loosen, so that it is in fact tantamount to a confession that the rivets are highly stressed when regulations call for frequent inspection of rivets. The matter of comparative rivet units will be more fully brought out, subsequently.

A comparison between European and American bridge practice would seem to call for mention of the one marked difference in practice or, in other words, the distinctive American practice of building pin-connected bridges.

Pin-connected bridges and eye-bars seem to be practically unknown in Europe. In one notable exception the eye-bars of a suspension bridge were cut out of wide plates. Forged eye-bars 2 in. by 12 in. in cross-section, with heads about 3 ft. in diameter, and 10 in. or 12 in. pins weighing a ton or more each, are not uncommon in moderately large American bridges.

The growing tendency to use riveted bridges in spans up to 150 ft. or more in America is sometimes interpreted as indicating a failure of pin-connected bridges to meet the requirements. The actual strength of pin-connected bridges is nowhere doubted among

American engineers. It is other considerations that make riveted bridges preferable for short spans. Some of these are,—greater rigidity of solidly riveted spans, increasing facilities for driving field rivets by use of power riveters, and greater ease and directness of connecting lateral braces to riveted girders or trusses.

Even in the days of very light highway bridges and pins of totally inadequate diameter, it was seldom if ever the cause of a failure that a pin was bent or an eye-bar broken in tension. Pin-connected bridges are not discredited by being displaced by riveted bridges up to certain span lengths, any more than truss spans are discredited by being displaced (as they are in this country) by plate-girder spans up to 100 ft. or more in length. Many American specifications make this clear by showing preference for I-beam bridges up to a length of about 25 ft., plate girders for spans from this limit to 90 ft., plate girders or lattice girders from 90 to 120 ft., lattice or pin-connected trusses from 120 to 150 ft., and pin-connected trusses for spans over 150 ft. These several different classes of girders or trusses have each their appropriate use. European designers do not have the same choice that American designers have, partially on account of their preference or prejudice, and partially on account of lack of facilities in their shops to turn out pin-connected bridges and forged eye-bars.

The absolute certainty of the strength of eye-bars and pins, when proportioned according to the requirements of any standard specifications, the practical impossibility of their working loose or needing periodic inspection, ought to make these features of design worthy of the study of engineers who are responsible for the safety of the traveling public. Speed of erection and economy are factors that American engineers also consider of great weight.

American engineers try to build their bridges so that the need of periodic inspection after completion is reduced to a minimum, or is entirely eliminated. It is true that many bridges in America seldom or never are visited by an inspector competent to pass upon their condition from any standpoint except as to their need of paint. The writer has examined many such bridges where all the evidence pointed to this; even the paint brush on many of them had evidently not been applied after the initial coat. Apart from excessive rusting in unusual conditions, and bad conditions of supports (particularly roller bearings), the writer has not found that these same bridges have suffered from lack of this inspection. To be more explicit, he has seldom found rivets loosened by the action of the loads on a bridge.

Bridges that are properly designed and not overloaded practically never wear out.

It is more economical and preferable in every way to design bridges so that they will not need expert inspection after they are once completed, than to anticipate that inspection by any feature of the design. Such inspection as the ordinary employees about a railroad could give, to detect deterioration from rust, displacement

of shoes, etc., will of course be necessary, but even the latter ought not to be required. Periodic painting is a good practice in any event.

An example of the need of expert inspection of a finished bridge is known to European as well as American engineers. This might be cited by someone as contradictory of the foregoing two paragraphs. The case of the Brooklyn bridge is referred to. By a drop of the floor of this bridge some years ago it was discovered that progressive failure had taken place in the hangers of the bridge. This could no doubt have been discovered by thorough expert inspection before it showed up by the dropping of the floor. But this is not a case of the wearing out of properly-designed members. The fault was in the design. The hangers which failed were short, being at the low part of the cable, and there was a wide amplitude in their swing as the bridge contracted and expanded, for the expansion joint was located at the low point of the cable. Besides this, the large expansion at the shortest hangers would of course throw extra weight on these short hangers. The rocking and the extra weight on these short hangers were too much for them and gradual failure resulted.

There are three principal causes that would affect the relative cost or weight of bridges in America and Europe, namely, the loads carried, the unit stresses allowed on steel, and the character of the designs.

There seems to be no doubt that the weights of engines and trains in America are much greater than those in Europe. What is said to be the most powerful locomotive in the world is described in *Railway Age Gazette*, June 13, 1912. The estimated weight of the 16 drivers is nearly 480,000 lb. The maximum tractive effort, compound, is 115,000 lb., and simple, 138,000 lb. This with long trains of cars weighing 40,000 to 50,000 lb. and carrying 100,000 to 120,000 lb. each would scarcely be duplicated in Europe.

In the matter of unit stresses there is not a great deal of difference apparent on first inspection of members in tension and bending, the units used on European bridges running from about 10,000 lb. to about 16,000 lb. per sq. in. (Only unit stresses on steel are considered in this paper.) It is true that many American specifications use units much larger than 10,000 lb. per sq. in., but they include in the stresses a fictitious stress called impact. A few American roads use less than 10,000 lb. of a unit but they employ a fatigue formula in connection with the same. European engineers are to be commended for not taking up with either the fatigue or the impact fad. There is very little rational ground for the use of either. They are the outgrowth of laboratory tests on small specimens and have scarcely any relation to a real structure. American engineers have almost completely dropped the fatigue formula, but they have in a large measure swung over to the impact formula, which is nearly as bad.

In the European regulations the unit stresses are varied with

the length of span or with the imminence of the members in stress to the live load. These are rational requirements, for they treat a bridge as a bridge and not as a laboratory experiment. In the writer's opinion, however, they could go farther and use lower units for members subject to sudden shock, such as floor-beam hangers. They should also make a distinction between live load and dead load stresses.

The best set of units in common use is Cooper's Standard Specifications. These recognize the two facts that stand out pre-eminent in the action of structures under stress. One fact is that dead load stress is not so destructive as live load stress. The other is that the more remote a member is from the application of the moving load, the less destructive will be the stress produced. American specifications that make use of impact formulas do not rightly take those facts into account, though they tend, in a general way, toward somewhat similar results. European specifications only very imperfectly make allowance for these facts. While they use higher units for short spans, they do not differentiate between dead and live load stresses in any spans.

The Prussian regulations allow on main tension members 12,100 lb. per sq. in. on steel for spans of 66 ft. (without wind stress) stepped up to 15,600 lb. for spans of 656 ft.

The French regulations allow 12,100 lb. per sq. in. on similar members without mentioning span length, though a subsequent paragraph allows units not to exceed 16,360 lb. for spans over 98.4 ft.

Cooper's specifications allow 10,000 lb. per sq. in. for live load and 20,000 for dead load.

The specifications of the American Railway Engineering Association allow 16,000 lb. but use an impact formula.

In a 100 ft. span, a tension chord having a dead load stress of 100,000 lb. and a live load stress of 200,000 lb. would require an area of 24.8 sq. in. by the Prussian and the French regulations. By Cooper's specifications it would require 25 sq. in. and by the A. R. E. Assoc. specifications 28.1 sq. in.

In a 500 ft. span, a tension chord having a dead load stress of 1,200,000 lb. and a live load stress of 1,500,000 lb. would require areas of 181.2, 165.0, 210.0, and 222.7 sq. in., respectively, by the specifications named in the last paragraph. It is thus seen that there is not much agreement between European and American practice in the proportioning of main tension members, and American bridges are apt to be much heavier from this cause.

It may be well to explain here that the specifications of the A. R. E. Assoc. require the addition of a fictitious stress, called impact, which is equal to the product of the live load stress and the

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fraction $\frac{300}{300 + L}$, L being the loaded length of track in feet producing the maximum strain in the member.

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In the matter of the design of the floor system, there is very little difference between the European regulations and Cooper's specifications, the former allowing 10,670 lb. per sq. in. and the latter 10,000 lb. The A. R. E. Assoc. specifications, while they allow 16,000 lb. on dead load, plus live load, plus impact, would require areas agreeing closely with the others in ordinary cases.

In the design of compression members, the greatest difference exists between European and American practice. The French regulations allow the same units in compression as in tension. The Prussian regulations also allow the same units but apply the Euler formula with a factor of safety of five, presumably where it has application, namely, in the longer columns. Facts do not support this practice, for compression members are far from being equally strong, unit for unit, with tension members. Tests of full-sized columns show something like three-fourths as high an ultimate breaking load per square inch as tests of full sized eye-bars. It is hard to see how consistency can be claimed for regulations that allow equal working stresses on the two. Any such system of units, if it does not result in failure, must surely produce structures that are much weaker relatively in their compression members than in their tension members. The reverse ought to be true for the sake of safety, for the action of compression members is not nearly so well understood as that of tension members, which is also true of their strength. Furthermore, imperfections of manufacture affect adversely the strength of compression members more than they do the strength of tension members.

The Euler formula, while it shows the ultimate strength of very slender columns, has no application to columns of ordinary length such as are used in railroad bridges. It is hard to see why it should be used in specifications for railroad bridges. Columns of commercial sizes and manufacture will fail by local buckling or crimping long before the Euler load is realized. It is this real strength of real columns that is of interest to designers, and not the fancied strength of hypothetical columns of unlimited compressive strength.

American specifications, while they often employ the same unit in the column formula as that used for tension members, reduce that unit by an amount depending on the ratio of the length to the radius of gyration of the column. Thus, compression members are designed with lower unit stresses than tension members.

The A. R. E. Assoc. specifications allow on compression members

$$16,000 - 70 \frac{1}{r}$$

Cooper's specifications allow on chords

$$10,000 - 45 \frac{1}{r} \text{ for live load strains}$$

$$20,000 - 90 \frac{1}{r} \text{ for dead load strains}$$

On posts, Cooper's specifications allow about eight-tenths to nine-tenths of these loads, thus consistently reducing the unit for members closer to the application of the live load.

The use of the straight-line formula as practiced by American engineers is better than a formula of the Gordon-Rankine type, because it gives values agreeing more nearly with tests. Whenever a column exceeds in length one or two diameters, its ultimate strength quickly falls away from that of the steel in short blocks. The straight-line formula expresses this, but the Gordon-Rankine formula does not.

Much of the apparent excess weight of American bridges as compared with European bridges could readily be explained by the unwarranted confidence in compression members shown by European regulations. The safety of European bridges is possibly enhanced by the inevitable riveted connection and riveted tension members, which stiffen the compression members at the ends. Many American bridges, of course, are pin-connected and lack these features.

In the matter of the value of rivets, there are other great differences between European and American practices.

The French regulations allow for shear, four-fifths of the unit stress in the pieces riveted and say nothing of bearing. They allow 4,270 lb. per sq. in. tension on the heads. Thus the shearing values would run from 6,050 to 8,180 lb. per sq. in.

The Prussian regulations allow in shear on the rivets nine-tenths of the unit stress for main trusses or girders, which would be 10,900 to 14,040 lb. per sq. in. In the floor system they reduce the unit stress by 50 kg. per sq. cm., which would give values ranging from 9,250 to 10,670 lb. per sq. in. In bearing they allow double these amounts.

Nothing is said in either of these European regulations regarding lower values for field or hand-driven rivets.

Cooper's specifications allow 9,000 lb. per sq. in. for shear and 15,000 lb. for bearing on main members, 7,200 lb. per sq. in. for shear, and 12,000 lb. for bearing on floor system.

The above values are for shop rivets. Field rivets are given only two-thirds of these values.

Thus field rivets in the floor system are good for only 4,800 lb. per sq. in. in shear and 8,000 lb. per sq. in. in bearing by American standards which neglect impact, whereas European standards run from 25% to 100% more than this.

The A. R. E. Assoc. specifications allow 12,000 lb. per sq. in. on shop rivets and 10,000 lb. on field rivets, doubling these values for bearing. On the basis of actual stress (eliminating impact) the units work out about 55% to 90% of these values.

It is thus seen that judging from these standards the confidence of European engineers in the strength of rivets is much greater than that of American engineers. The writer fancies that he sees in this, ground for the different attitude respecting tests and periodic inspection in Europe and America.

The details of a bridge are extremely important factors in the strength and life of the structure, particularly the end connections of the members. The writer has found bridges that would have had their useful life greatly prolonged (through the period of development of increased train loads) by the expenditure, in their original design, of trifling amounts in stronger details. A half dozen or so of additional rivets may increase the actual strength of a member by a very large percentage. Hence liberality in detail designing, though it may add but a little to the cost of a bridge, can be made to add enormously to its real value as a carrier of loads.

Another feature in the comparison lies in the failure of European regulations to recognize the relative weakness of hand-driven or field rivets as compared with power-driven or shop rivets. Practically all American specifications recognize this and require more rivets, if they are hand-driven, than would be required if they are power-driven. This regulation further serves to increase the number of rivets in the end connections of truss members and of beams, since these rivets are usually driven in the field.

It is in the end connections, and possibly nowhere else, that rivet failures and rivet weakness should be looked for; hence the double importance of low units for these.

Another fact that has an important bearing is the uncertainty as to the strength of rivets. The entirety of compression and tension members can be visibly determined, but rivets may appear tight to the hammer and yet fail to fill the holes. Again, the heating of rivets may be improperly done, and their strength may be impaired by this means. The writer has found rivets from which the heads had "popped off" after driving.

In view of the foregoing facts, the wisdom of using low unit values for rivets, particularly field rivets, as required by the best American specifications, cannot be too highly commended, especially since these units bear a reasonable relation to the unit stresses in the members and are therefore not extravagant.

The writer finds nothing to commend itself in the European practice of using shearing units on the rivets as a large fraction of the unit stresses in the members. This does not comport with the actual shearing strength of steel, nor with the actual strength of rivets at first slip, nor with the fact that rivet steel is a softer grade than that from which the members are made. Besides this, it does not take into account the neglected element of bending on rivets.

A set of American bridge specifications is a compendium of rules of design. They take away from the designer the exercise of judgment in many matters. This is an excellent thing. It is safer to carry loads on steel than on judgment. The designer is, of

course, not restricted if he wishes to make his structure stronger, but he is estopped if he wishes to introduce his opinion in the design and cut down the strength of details and members.

European regulations seem to contain nothing relative to bridge design apart from the loads and unit stresses and other general requirements. The space that in American specifications would be taken up with detailed requirements and methods of design is employed in these European regulations with descriptions of tests, test loads, and periodic inspection.

American specifications, furthermore, go to great length in describing how the shop work must be done, when holes may be punched and when they must be reamed or drilled; when plates may be sheared and when they must be planed, and a large number of other things that make for first class work. The European regulations contain nothing of these details.

Specifications that tell just how shop work must be done are an excellent thing in the hands of an inspector. They leave no doubt as to just what he may demand of the manufacturer, and do not place him in the difficult position of pitting his opinion against that of the manufacturer.

Specifications that tell just how bridges are to be designed and detailed are an excellent thing in the hands of a consulting or checking engineer for similar reasons.

Uniformity and fairness in competitive designs are advanced by this elimination of personal opinion.

Ideal specifications are those which, when a bridge is built in accordance therewith, it will need no testing upon completion, it will need no after inspection, it will need no brooding-over by periodic inspection. American specifications tend toward this ideal, and in a large measure realize it. European regulations do not, if we can judge by the Prussian and French regulations cited in the first part of this paper.

A few details of girder spans that came to the writer's attention show some astounding things. These appear to show standard English practice, as they were for new bridges and not details of ancient work. Furthermore, they were for railroad service.

The top laterals of one of these spans consisted of angles in one direction and flats in the other direction. This would not be thought of by any American bridge engineer worthy of the name.

The end connection of the end lateral in a 60 ft. span was *two rivets!*

The flange of this 60 ft. girder consisted of two 4 by 4 by $\frac{1}{2}$ in. angles, one plate 16 by $\frac{3}{8}$ in., and two plates 16 by $\frac{1}{2}$ in. About 25% of the flange section was in the angles, whereas American practice frequently demands 50%. American bridge engineers would use 6 by 6 in. angles and eliminate one of the cover plates. Cover plates twice as wide as the flange angles would be considered very bad designing in America. Such design was used here **forty** years ago, but it has long since been discarded. The writer has in

mind a girder span with small flange angles and wide cover plates, designed very much like this one, that after a generation of use, failed in 1900, under the most ordinary service, and resulted in the death of two men. He calculated the flange stress and found it to be not at all excessive, though clearly the flange ripped apart in tension.

Another fault with these small flange angles, in addition to their failure to distribute the stress out into the wide cover plates, is that only one row of rivets can be driven in the angles and the web. Good practice in girders of this size invariably demands two rows of rivets in the web in order to take care of the flange increment near the ends of the span.

The intermediate stiffeners and intermediate sway frames of these spans show some more astonishing details, as shown in the illustration. It would not be difficult to picture the actions of an American bridge shop manager who would be asked to make this kind of work. It is exceedingly difficult to imagine the kind of reasoning that would evolve it. This is the intermediate section of a 30 ft. girder span 36 in. deep. A 50 ft. span has practically the same section, except that the stiffener angles are $3\frac{1}{2}$ by $3\frac{1}{2}$ in., and only one size of rivet is used. What is still more surprising is that the end sway frame of the 50 ft. span has the same size of cross bracing with only two rivets in the end, and the 60 ft. span, while it has $\frac{1}{2}$ in. angles, has only two rivets in the end connections.

In comparing this simple figure with well-known American standards there are so many comments that can be made favorable to American methods that it is difficult to know where to begin. These comments bear on economy, efficiency, and safety. In all three, American standards are vastly superior.

The intermediate stiffeners of these spans are the same as those at the cross frame. That is, they consist of two gussets, two forged angles, and two fillers against the web. American designers would use two angles, offset or crimped for the flanges of the girder, or, at most, two straight angles and two fillers. The office of intermediate stiffeners is to stiffen the web plate against buckling. This can be efficiently done by a single pair of angles, saving the expense of cutting and fitting two gusset plates, forging and fitting two angles, and driving a lot of extra rivets.

American designers aim to reduce the number of sizes of rivets used and to use only one size in a piece if possible. The illustration shows two sizes of rivets in the stiffener angles, thus further increasing the expense of their fabrication.

It is hard to see why fillers should be used against the web in the figure, as the angle itself could be brought in contact with the web.

A 15 ft. span of this same set of standards has the same features of design, including small angles, a wide cover plate, six-piece intermediate stiffeners, and even four-piece intermediate and end sway frames for girders only 18 in. deep (in place of channels as

American bridges would be designed). In fact, American bridges of this span would probably be of I-beams.

The end stiffeners of these 50 ft. and 60 ft. spans were like the intermediate stiffeners with the addition of angles at the outer edges of the plates, as indicated at the right hand end of the illustration. Could anything be more absurd? An end stiffener is a column to carry the reaction of a girder into its web. What would be thought of an assembly of crooked and disjointed pieces such as this, taken apart from a girder and made to act as a column in any other kind of construction? End stiffeners, as American designers make them, consist of straight angles abutting squarely, with close fit, against the bottom flange angles of the girder.

If details of design in other classes of bridges are on a par with these standards in girder design, it does not appear that American engineers have anything to learn along these lines from the other side of the water.

DISCUSSION.

I. F. Stern, M. W. S. E.: (Chairman). It is gratifying to feel that we are the best designers in the world. In fact, we seem to acknowledge it ourselves. But I do not think we should fall into the error of assuming that *all* European bridge design is bad because some isolated instances have been found where the design was atrocious. In American bridge design we also find some bad things, and when we look at the earlier designs, we find faults occurring with more or less regularity. It would have been interesting if the author had told us whether the particular girder described was one which had been built in recent years, or one that had been in existence for some time. I suppose anyone who has been in practice for any length of time, especially if he has been connected with a railroad and has gone over bridges that have been built on that railroad, say, twenty-five years, could give instances where the designs were practically as bad as the European design. The thing which impresses me, in the sketch shown, is that Europeans seem to have had the same tendency that we had in our earlier bridge designs. That is to say, they put everything in the forge shop and forge or blacksmith their members. We used to do that, but by judicious consultation between the bridge engineers and the bridge companies, we have discontinued that practice.

In a trip over the Intercolonial Railway in Canada, I was much impressed by evidences that tended to show diametrically opposite from what the author has given in his paper. The bridges on the Intercolonial Railway are much heavier than I have ever seen on American railroads. I found, for instance, in long spans where they had 25 ft. panels, it was not uncommon to find two stringers under a rail, each stringer 6 ft. deep. That was the latest practice and their general bridge inspector naively said that when this was done it was unnecessary to examine them.

Personally, I believe in periodical inspection, but that may be due to preliminary training. We all go by what we have done, and see, more or less, the necessity of doing things the way we have done them.

The author should have remembered that on all American systems there are a large number of old bridges, and I should say that all of these ought to be inspected. In fact, the whole road should be inspected periodically, even if there is some odium attached to it.

President Reichmann: This is a very interesting paper, and I make the suggestion to the author that he have the specifications of both the German and French Governments translated and appended to his paper, because it would enable engineers to make comparisons in detail.

The author comments on the difference in weight of the European and American bridges, due in part to the heavier traffic on the American railroads. I think this is due largely to the different conditions which prevail here and in Europe as to the length of haul and nature of freight. In the European countries (which are all small in area and densely populated in comparison to the United States), for instance, Germany and France, the haul is much shorter; their waterways have been developed to a greater extent, resulting in the shipping by water of a larger portion of their heavier freight, and the railroads taking care of the lighter commodities. I believe this is one reason for their lighter train loads. We frequently have cars traveling 1,000 to 2,000 miles before the loads are changed, and a great deal of our products, such as grain, iron ore, coal, etc., permit the loading of a car to its maximum capacity. I believe it is a question of economy, depending on the nature of the freight, whether cars are hauled partially or fully loaded. Unless it is possible to load cars to their full capacity, the percentage of weight of the dead load or equipment becomes too great. In the ore regions, in local traffic, the haul of car and contents amounts, in weight, to about 6,700 lb. per lin. ft. Then, again, there are roads that do a coal business, and they have their particular loading, and in the grain regions I suppose they have a still lighter load. So conditions in America vary according to the freight that is hauled over the particular roads.

The author does not seem to think well of the impact formula as adopted by the A. R. E. Assoc. I believe the formula is the best we have been able to devise, up to the present time, to take care of the varying conditions of the effect of the live load on the spans. For instance, Cooper's specifications give a certain tension for one member that receives suddenly-applied loads. Then, again, the compression formula varies for the columns which receive more or less local bending, and that also receive loads rather suddenly. That, I think, is more of a rule-of-thumb way of going about it, and does not secure as good results as would be the case if the A. R. E. Assoc. formula were used.

Of course, the impact formula, as it is used, is probably excessive, but I have heard people refer to this fictitious term as "the factor of ignorance." There is so much that we really do not know about the action of stresses on members. It is only within very recent years that we have considered carrying the stress into a compression member so as to distribute that stress properly over the member. We used to figure out the number of rivets required for the bearing and then provide a sufficient number of rivets to take care of the bearing on the pin plates. Now we try to carry the stress into the member, and that is a very important thing.

Then, again, on certain chords and parts we are likely to get eccentric and secondary stresses, due to floor-beam and lateral connections, which stresses are looked into and taken care of.

There is one subject in the specifications, to which I have given a great deal of thought, and that is, the value of rivets. I think our American engineers do not give this matter sufficient consideration; they do not discriminate between rivets that merely hold the parts together and rivets that are subjected to shear or bending. I think our practice is good where we get more or less bending in rivets, and I do not recommend any change for that condition. On the other hand, I think we use altogether too many rivets in our members where we merely put in rivets to hold the parts together. For instance, in tying compression members together, and in the flanges of our plate girders, I think we weaken the members by putting excessive rivets in them. Take a deck plate girder; that has a certain local bending at times when the train passes over the bridge; the same number of rivets are put in the through plate girder as in the deck plate girder, when, as a matter of fact, we require more rivets in the deck plate girder than in the through plate girder. This practice is due to a sort of flat rule.

When we come to a large span, I think it might be well to use a 1 in. or $1\frac{1}{4}$ in. rivet. I do not know that all our shops could drive $1\frac{1}{4}$ in. rivets, but I think a great many of them could drive 1 in. rivets. The latter have 30% greater value than $\frac{7}{8}$ in. rivets. In heavy work, the specifications usually require that the holes be sub-punched, and in many instances the sub-punched holes are so small that it is almost impossible to get a proper fitting up bolt in the hole to draw up the work so that it can be properly reamed and finished. I think, in a case of that kind, if we would use 1 in. rivets and less of them, we would be in a position to do better work in assembling.

The author also says that very little mention of workmanship is made in European specifications. To me that is perfectly clear, and I can see why they do not do it. Their methods are very uniform, and they drill practically all their work out of the solid. They have only one kind of workmanship, and that is the reason that European people do not specify details of workmanship. Our methods vary a great deal more than in Europe, and I think they

should. In a certain class of work we punch the rivet holes, another class we ream, and another class we drill the holes out of the solid. I do not believe in specifying methods, but I do believe in specifying results. Let the man who has ability develop his methods. Of course, there are cases where it is necessary to specify methods, but I do not think an engineer should do it where he can possibly avoid it. He should specify what he wants and let the manufacturer specify the methods.

I think there is no subject that receives more consideration in our railroad offices than the inspection of bridges. I believe our bridges are watched carefully, and that they are not only guarded in the office but in the field as well. While some of the roads may not have what they call periodical inspection of bridges by expert engineers, still I think that on almost all roads there is an inspection. It may not be performed regularly, but my experience has been that the records in the office are always kept in first-class shape; they know exactly what bridges need attention and these are always carefully guarded and watched. As far as inspection goes, I believe there is no place where bridges are given better attention than in America.

W. S. Lacher, Assoc. W. S. E.: Mr. Reichmann calls attention to the positive statement of the author as to his preference for Cooper's specifications or the Cooper method of design. There is one advantage of the A. R. E. Assoc. specifications which seems to have been overlooked, and that is the fact that the stress which we use in design is really the stress that we get in the structure if it receives the same loading that we use in the design. That is, if we use the 16,000 lb. tension stress in design, we expect to actually get that stress in the structure with the same loading, provided we actually get the impact which we assume that impact formula will give us. When you use, say, 10,000 lb. for dead load and 20,000 lb. for live load, what is the stress in the structure when it is loaded? It cannot be both. Then, again, in investigating old structures to determine just what the old structure is good for, the A. R. E. Assoc. specifications are much more flexible and much more convenient to use. It is necessary to work backward. We must start in with a stress, say, 16,000 lb., or, as provided by the A. R. E. Assoc. regulations for classification of old structures, 26,000 lb. It would be awkward to attempt to use a double system of stresses in such a case. That is, it would have to be 26,000 lb. for dead load, and double that—52,000 lb.—for live load. Then, again, it does not always come out just even that way. One should investigate a bridge for a certain locomotive to determine not only whether that locomotive can be used over it at all for unlimited speeds, but also whether that locomotive can be used for slower speeds if limited by a slow order, to, say, fifteen miles per hour or even five miles per hour, for which purpose we would want to modify the impact coefficient.

Experience with problems of this kind has shown that the
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Cooper system of design, or Cooper specifications, are awkward to use.

Mr. Stern: The best thing in the Cooper specifications, to my mind, outside of the fact of the primary specifications, is the little statement that is always made that every set of specifications is intended to be interpreted in the light of common sense and good judgment based on previous experience, and I think that is the crux of the matter.

I am very glad to have seen this matter of impact taken up by the two previous speakers. It is not only a theoretical proposition, as the writer assumes, but it is an actual thing that we have with us every day. The last experiments that I know of were those made by the sub-committee of the iron and steel structures committee of the A. R. E. Assoc., which Professor Crandall of Cornell University, and Professor Turneaure, Dean of the University of Wisconsin, conducted here. I was with them on some experiments for the C. & N. W. Ry., where we gave them an engine and a train of coal cars. The results obtained were really remarkable. Impact, as the tests showed, and as our modern designers contend, and as Mr. Reichmann has said, not only takes care of the added stress due to the sudden imposition of a load, but of the eccentric stresses we get in practically all members, no matter how carefully they are designed. The eccentric stresses were tested by these gentlemen by having extensometers at four corners of the members. They tested C., M. & St. P. Ry. bridges, C. & N. W. Ry. bridges, B. & O. R. R. bridges,—in fact, bridges all over the country,—and it was remarkable to find the amount of eccentric stresses that were developed in the members that were designed according to the highest standard known to American practice. But it is peculiar, too, that in many instances they found that the addition to the normal axial stress due to a dead load or passive load was just about what the formula for impact would give.

I also agree with both speakers that it is best to try to determine how much stress comes into a member and then take a proper unit stress. That has been the cry of all of the good designers and those who have made the specifications by which we are guided.

C. R. Dart, M. W. S. E.: I have noticed plans of English girders with cover plates piled several inches thick on a single pair of flange angles, without any side plates between the angles and the web. Forged angles are used frequently and one may see diaphragms with the marginal angles forged into continuous one-piece frames.

Regarding provisions for the effect of impact. Cooper's specifications require that unit stresses for live load shall be half those for dead load. Most specifications, however, increase the live load or the live load stresses by an allowance for impact which may be arbitrarily assumed, or is based upon the length of loaded span causing the stress, or upon the relation of live load to total load.

The A. R. E. Assoc. specifications provide for an impact which

decreases as the loaded length of the span causing the stress increases, but does not distinguish between heavy and light structures or between open floors and solid ballasted floors. Other formulæ, basing the impact addition on the ratio of live to total load, do not directly take into consideration the difference between suddenly applied and gradually applied loads. It would seem that a formula combining the effect of the length of span loaded and the ratio of live to total load would give more nearly the true stresses. Cooper's highway bridge specifications do this, in a way, by providing a lower unit for live load stresses and by reducing the assumed live load per square foot as the length of span increases. These specifications, however, do not cover or are not clear on many points and perhaps leave too much to the judgment of the designer.

As to rivets, I have always favored being on the safe side. In most connections I would add rivets to the calculated requirements for a connection to compensate for unequal distribution of the stress on the rivets and for secondary stresses not ordinarily taken into account. Rivets are not expensive, and it is generally better to develop the full strength of each member, in its connections, than the full strength may be available, if ever called upon by an increase in loading.

W. F. Jordan, Assoc. W. S. E.: The author made a reference to tension in rivet heads, and stated that the French allow something over 4000 lb. per sq. in. for a tension rivet head. In preparing details, a question that comes up with us very often is whether we can allow anything for tension in rivet heads, especially for heads of field rivets. Most specifications we have to follow make particular reference to this by saying that nothing will be allowed for them. In detailing mill buildings in particular, a great many conditions arise that require connections in which it is necessary to put rivet heads in tension, or else use bolts. Of course, I know that these conditions do not arise so often in bridges, but I would like to hear some expression of opinion on the subject.

Mr. Dart: While I think one should avoid placing tension on rivet heads, cases sometimes arise where it seems necessary to do so. When such a connection fails it is generally due to an eccentrically applied load causing the connection to strip off, starting at one end and progressing to the other end. If the line of stress intersects the rivets so as to keep the pull on each within safe limits no trouble is likely to occur. Of course there is always an uncertainty as regards the initial stress in the rivets, and heads sometimes do pop off at any time after driving.

Mr. Stern: Based upon what I have seen, I do not think I would allow any tension on the heads of the rivets where I could put in bolts. The author brings forth the fact, which I have seen in practice in the field and which those of us who have been out on erection work have doubtless all noticed, that very often a rivet

head will pop off after it has been driven. The shrinkage stresses, of course, are very great and they pull the rivet heads up tight against the plate. That is one of the good elements in taking care of a connection, because the plates are tightly held together and slip does not occur. Those of us who have seen heads of rivets pop off are not apt to put much reliance upon tension in the heads of rivets.

F. G. Vent, M. W. S. E.: I observe on the diagram, evidently of an English bridge, 4 by 4 in. angles with two 18 in. cover plates. The question was raised as to the date of this bridge. The author says it is one of the late bridges, and I notice it is a modern design. I do not find any mention of an English driver load, and it would be interesting to know what that is, especially for a deck bridge. If it is like the Prussian railroad design, there would be about 44,000 lb. on the drivers; if it was a deck girder we might find that the flange rivets had considerable stress from the driver load or the local load, in addition to the transfer of the stresses into the girder. To me it seems like a weak design.

E. B. Wilson, M. W. S. E.: In regard to the question of rivet heads popping off, I once saw a flange of a 50 ft. girder stripped from end to end with a hammer. Some of the heads fell off themselves and the others came off with slight tapping. I do not place much dependence on rivet heads in tension.

President Reichmann: Mr. Wilson, did you investigate the cause of the rivet heads popping off?

Mr. Wilson: We tried to go into it, but we finally had to go back to the question of steel. Some of the rivets had the appearance of being burnt, and there was the old question of crystallization on account of improper heating at the time they were driven.

Mr. Stern: Were they shop driven?

Mr. Wilson: Yes, shop rivets all through.

A Member: Were they new rivets?

Mr. Wilson: Yes, new rivets. They were easily knocked off; in fact, I think the whole top flange of the girder could have been knocked off without very much trouble.

President Reichmann: The American Bridge Company, at its Ambridge plant, made a series of tests on tension rivets. The rivets showed up very well: much better than we had expected. We made the test for this reason: In office building work there are a great many connections where rivets are subject to tension, such as brackets supporting "I" beams. We had the tests made to satisfy ourselves as to whether those connections are really of the strength that they ought to be.

Mr. Stern: What was the objection to putting in turned bolts?

President Reichmann: It is not done in office building work. Every business has its custom, and it is not the custom in that line of business.

W. M. Wilson, M. W. S. E.: In working with a set of specifications for a bridge for the Swedish government I had occasion recently to notice, in connection with the specifications, a formula for governing the unit stress which seemed to me very sensible and very easy to use, although I have not taken the time to make any numerical comparisons with the American formula.

This formula is to allow unit stress of tension members of 800 kilograms per square centimeter into the quantity of 1 plus a constant into the minimum stress over the maximum stress. Where the minimum and maximum stresses are of opposite signs, the quotient is negative.

In addition to this formula there is a live load impact based upon the load span. Then we have this formula in connection with this table taking care of three points: the relation of the impact to the length of the span, which is taken care of in the A. R. E. Assoc. specifications; then the point which Mr. Dart brought up, the relation of the impact to the relation between the dead and live load stress; and, finally, where the sign of the quotient is negative, making the allowable unit stress 800 into 1 minus a certain quantity. We have a reduction in unit stress taking care of reversal.

As I say, I have not made any calculations to determine how this formula compares with American practice, but it looks to me like a very logical form and it is in a very simple form to use.

Mr. Vent: My remark about local loading on the deck girder applies to stringers.

In regard to the impact formula developed by the A. R. E. Assoc., some roads use a formula I , being, impact-percentage equals 300 divided by L plus 300, and for stringers or short spans they add also, 100 minus L , divided by 500, L being the loaded length of span. The impact will amount to 120% of the live load. With the other designs, we sometimes neglect local concentrations in figuring flange rivets, and when we take a rivet value that is allowed by the specifications and figure the big impact, the rivet would be over-stressed considerably if that were neglected on a stringer.

Referring to loose rivets, we look to a stringer connection, or parts held by the flange rivets, for the first symptoms of rivet failure. It is a point to be given careful attention in the design.

Mr. Stern: In the examination of some bridges that had stringers and some that were deck girders, with a uniform spacing of 6 in. in the flange rivets, I have never yet found a loose rivet in the flange angle of the stringer or girder that could not be absolutely shown to have been loose at the time of manufacture. I have talked with other inspectors who have gone over the various roads, and I know of only one or two instances in an examination on the part of these various inspectors, covering probably 10,000 bridges, where there were any loose flange rivets.

Mr. Vent: In speaking of loose rivets I might have made a
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distinction between "loose" and "over-stressed" rivets. We all know that flange rivets as a rule remain tight; however, they may be considerably over-stressed and still remain tight, for the reason that very little tension is developed upon their heads on being over-stressed by a nearly direct shear. My idea is to give them the same liberal design as the other parts of the girder. We can look for most of the "loose rivets" in the connection of stringers to floor beams, and floor beams to trusses, for the reason that these are subject to rivet head tension due to deflection, in addition to the direct shearing stress, unless tie plates or their equivalent are used to prevent this, and they may be found loose from rivet head tension, even though the direct shearing stress may not be excessive.

President Reichmann: In that connection I will say that about a year and a half ago two railroad companies were using a certain bridge. One company wished to increase the weight of traffic over that bridge, and the other company used the bridge only as a side line. They each had to pay half. The second road did not care about paying for a new bridge. The chief engineer of the first road thought he might condemn the bridge as being too light, and asked me to make an examination of it, to see if he could take such action. The bridge was much over-stressed, and yet I found but one loose rivet on the entire structure, and that loose rivet was at the end of a stringer connection. I asked the chief engineer of the road if he ever had any trouble from loose rivets, and he replied that he never had any loose rivets. The bridge is about 30 years old.

O. F. Dalstrom, M. W. S. E.: The paper would have been more valuable if the author had stated the actual running loads on the European bridges to which these specifications apply.

In the Bridge Department of the C. & N. W. Ry., we have been studying the subject of specifications, and comparing those of other railroads, with a view of changing those now in use in that office, either revising them or rewriting them entirely. We have also collected what data we could find regarding the maximum loads on various lines. The heaviest axle loads that we found were those of a 4-4-2 type Pennsylvania R. R. passenger locomotive. The maximum load on one pair of drivers was 68,800 lb., and the average for the two pairs was 66,600 lb. The axles were spaced 7 ft. 5 in. between centers. Another Pennsylvania R. R. passenger locomotive, this one of the 4-6-2 type, had a maximum load of 62,000 lb. on one pair of drivers, and an average of 59,500 lb. for the three pairs of drivers. A number of locomotives, both passenger and freight, had average loads of from 55,000 lb. to 58,000 lb. on the drivers, and a maximum on one pair of drivers from 5% to 6% in excess of the average. From this it appears that specifications that provide for maximum concentrations of 60,000 lb. or 65,000 lb. are providing for loads corresponding very closely to the

maximum loads actually in operation on heavy traffic lines. If we had the maximum loads operating over those European lines to which the specifications apply, it would be interesting to note whether the relation between their actual maximum loads and those provided for in the specifications differs materially from the relation between actual and assumed loads in American design.

In regard to impact, I wish to emphasize a point which the author brings out in another part of his paper; that is, the importance of rules to secure uniformity in office practice—rules which do not leave important questions of design or detail to the individual opinion of the designer. In this respect Cooper's specifications are not satisfactory, because different men interpret them differently when it comes to classifying the members for the different unit stresses. The impact in the various members of a long truss span varies from sudden shock in the members of the floor system, to gradually applied loads in the chords; that in different web members being anywhere between these extremes. Cooper's specifications virtually classify all members carrying live loads into two groups,—those which are subject to sudden shock, and those which are not,—providing a special unit stress for each group and a third group with a special unit stress for the members of the bracing systems. The defect in this method is, as has been pointed out by Mr. Reichmann, that the provision for impact is not graduated to correspond to the impact to which the member is subjected. One member will be designed for a unit stress making ample provision for impact, while another member, subject to almost the same amount of impact, will be designed for a unit stress making provision for none.

Mr. Stern: I noticed in one of the late issues of *Engineering News* that a Mallet articulated engine is shown, that had six sets of drivers, and the entire load of the engine was taken on the drivers. It was a 0-6-0 engine. It had 300,000 or 350,000 lb. on the six sets of drivers. I would ask Mr. Dalstrom if, in his investigations, he found any Mallet engine that had any greater loads for that number of drivers, and I would also like to have him state the formula for impact used by the C. & N. W. Ry. Co. Mr. Dart raised the question of the necessity of the live load in its relation to the dead load on the bridge affecting the impact.

Mr. Dalstrom: I do not remember that we had anything that ran up to 60,000 lb. where there were more than three drivers. We had two or three Mallet's, one of them being of the A. T. & S. F. Ry., but I do not remember the others. In going over those I was interested at that time only in the local concentrated loads as they affected short spans, and I found that in each case the engine which gave the maximum results was a passenger locomotive. While there were some freight locomotives which would affect spans of 100 ft. more than the passenger locomotives which I have just mentioned, none of them entered into the question that we had

under consideration at the time; that is, the short span stringers for panels of through bridges.

The formula that the C. & N. W. Ry. Co. uses for impact is

$$\frac{l^2}{1 + d}, \text{ the same formula which has been in use in our office for a}$$

number of years, and there is no intention of changing that in the adoption of new specifications. We have been comparing that and looked up carefully the set of curves in the Siemens article in the Transactions of the American Society of Civil Engineers, for 1912, but after considering them all it has been decided not to make any change in our impact formula. It is still the ratio between live load and dead load, without any consideration of the length of the loaded part of the span.

Mr. Stern: In your new specifications, did you do any plotting on actual engine loads to show their relation to the Cooper diagram E-50, E-55, and E-60? What was the highest thing you found? Where would it come in the Cooper specifications?

Mr. Dalstrom: It came below Cooper's E-55, if I remember correctly. We made a number of diagrams at various times, comparing the diagram of the actual with the Cooper E engines, and while I cannot say off-hand just what the relation was, I think that E-55 would come quite close to the actual load that we had to deal with. I do not mean that was our Z engine on the Northwestern road, but the heaviest loads that we had found on other lines.

P. W. Leisner, M. W. S. E.: I am in a position to answer Mr. Dalstrom's question about live load. About eight years ago European engineers assumed a live load consisting of a 16 ton axle load on axles spaced about 5 ft. center to center for the engine, and a correspondingly low loading representing the train. This, I remember, had at that time been the standard maximum for many years, and I do not think the assumed live load has been increased during the last eight years. About four years ago I traveled in England, Holland, Germany, and Denmark, and, with the American railroad cars fresh in my mind, the European cars looked ridiculously small. In Denmark I asked several merchants and manufacturers why they did not build larger cars, and told them that it seemed to me this would give greater economy in handling. They did not agree with me, and said that the present standard sizes of freight cars are 12,000 and 20,000 lb. capacity; that if they were to have an additional size it would be a smaller one, as there was absolutely no demand for larger cars. It may be said in this connection that the private roads have many 6,000 lb. capacity cars, some of these for special purposes only, but all in great demand for general use. Now compare this light rolling stock with the freight cars used in this country, having capacities of 40,000 to 110,000 lb. and a probable increase above the 110,000 lb. capacity. As a

previous speaker has pointed out, the conditions on the two sides of the Atlantic are widely different. In Europe they will need exactly the same sizes of rolling stock in the next generation as they need in this, but in America new lands and new mines are being opened up, immense new industrial plants centralize production, and all products are to be hauled nearly across a continent. In Europe, where goods are to be hauled in large quantities, they go by water. Compare the map of America with that of Europe; North America is a compact sheet of land, while Europe is cut up into islands and peninsulas. Most of the rivers on the European continent are navigable, and canals for navigation are found almost everywhere.

It should be mentioned that 75 lb. rails are used on main lines in Europe, which may seem a heavy rail for the light equipment. This is explained by the fact that the travel in Europe is rapid, and the railroad ties are spaced up to 3 ft. 2 in. center to center.

What I have said will to some extent explain why the same specifications, but slightly amended, may be used for 22 years in Europe. It should not be forgotten, in making a comparison, that often when a larger live load is specified in this country a higher unit stress is permitted, and the tendencies in this direction during the last 22 years have been general, thus making the changes in specifications less severe.

Departing from discussing these special items of specifications, I would say that I think the author of this paper has not had access to all the information which relates to the subject of general specifications.

In Europe standard forms of specifications are but little used; a set is prepared for every bridge, building, etc. Such specifications will not contain instructions to draftsmen. Most of the governments over there maintain Polytechnical institutions at a large cost to the community. Such an institution is the authority on matters technical. The students leave the institution with the knowledge of what constitutes good engineering practice in the country, and the technical details may safely be left with them to be worked out. I think many things can be said in favor of the European method. The designing and detailing is turned over to men who have devoted five to nine years exclusively to studying and practicing, under instructors, engineering science and standard engineering methods. In engineering offices there are also men who make tracings and fancy drawings,—manual work which is their trade. No attempts are made to develop these men into engineers; it would require the introduction of drafting room specifications; and even if you make such specifications as voluminous as all the text-books of the engineering institution, you cannot make them fool-proof. These men have their trade and they stick to it and perfect themselves in it. The Europeans cultivate thoroughness. They may be somewhat slow, but I think as a rule they

do good work. Once a rivet is in place they know it will stay there until removed by some mechanical means.

The author criticises the Euler formula and seems inclined to scrap it, together with laboratory tests. The Euler formula finds application only to columns with a slenderness ratio of more than 125, and it is the only column formula we have been able to prove the correctness of by tests. Mr. Godfrey's reference to the real strength of real columns being of interest to designers, reminds me of an investigation I made some years ago to determine the strength of a bridge in Minnesota. One of the vertical posts, a compression member, had a slenderness ratio of 228. I watched the bridge while a train was passing at a moderate speed, and I must say the deflections vertically and horizontally looked dangerous, but the bridge had been used successfully for 30 years. According to the formulas advocated by Mr. Godfrey, the bridge should have been in the river before I had the opportunity to watch it, but it is still in place, now reinforced to carry heavier loading. I then investigated the column with the Euler formula, and found that it had a margin of safety, which seems to justify the European belief that the Euler formula has some practical value, at the same time disclosing one place where nowadays American engineers would put more metal in the bridge than would European engineers.

It would be useless for anyone to attempt to put up a defense for the English plate girder illustrated by Mr. Godfrey in his paper; it might be of interest, though, to know that they go much further with their flanges in England. I have seen several railroad bridges in London with plate girders made up of a shallow looking web, two flange angles with one row of rivets, and several cover plates, the plates wide enough to permit of an angle on each side of the other angles, making a channel section of the flange. The girders seemed comparatively old, yet they were doing their duty. Numerous trains daily pass at a high speed, and, talking of high speed, I remember Mr. Stern said, after returning from a trip to England, "they have the tiniest little engines and these tiny little engines will run away with you just as fast as you please." I have often wondered why the passenger locomotives here are so large and so heavy, because in Europe they do seem to make good time with their small locomotives.

Mr. Godfrey opens his discussion with the remark that the charge is frequently made that "Americans generally shave down the design to the last pound." This charge, if ever made by a party big enough to be heard by the engineering profession, must have been a mere guess. I have practiced for eight years in this country, and I think we put more metal in the bridges than they do over there, even making due allowance for the difference in weight of the live load. I have heard the Quebec disaster discussed by men abroad, and by listening to them I have found that they did not know what they were talking about, they had not gathered

enough data to go on, although they posed as engineers who had made a special study of the calamity. They entirely missed the point and their discussion of the subject may be repeated as a curiosity only. Barring such contributions to the discussion of the subject we have before us I should say or conclude that the engineers on both sides of the Atlantic deserve credit for the manner in which they solve the problems laid before them, widely different from each other as these problems are on the respective sides.

Mr. Stern: I think the speed obtained by the Europeans with their small locomotives is due to the roadbed they have. They have the most beautiful (that is the only way one can express it) roadbed in the world. If we tried to go over our roadbed at that speed, with the little engines they have, we would be in the ditch about three-fourths of the time. Their roadbed is very smooth and they haven't anything like the grades we have in this country. I suppose a three-tenths grade there is almost prohibitive. Here if we come down to a three-tenths or four-tenths grade we are doing wonderful work.

As Mr. Reichmann said, we make our specifications so that they are fool-proof, at least we try to. There are a great many things in a specification that experienced designers think they can modify, due to their previous experience. Recently, in the design of a little footbridge, I found, in using Cooper's specifications (and it was specified that they should be used), you could not have any

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light lateral struts with an $\frac{1}{r}$ of over 120; but I do not think it is

absolutely necessary to stick to that if you have a very light foot-bridge.

CLOSURE.

The Author: The purpose in writing this paper was not to pat American engineers on the back. The author has done considerable in the way of criticising the work and the standards of American engineers, both in reinforced concrete and in steel construction. He finds it to be true that structural steel designers will discuss faulty construction and can be brought to see its weakness, whereas reinforced concrete designers have not, as a rule, advanced beyond the infantile argument "it stands up."

Further, it was not the intention to condemn European railroad and bridge practice *in toto*. It no doubt suits the Europeans to haul their "wagons" with light locomotives and to brood over their bridges and test and re-test them. But only a knowledge of these facts can explain why their bridges are so much lighter than ours.

The author did not put forth the samples of European girder design because they were atrocious, but because they were all that has come to his notice in recent years. They are not old bridges, as intimated by Mr. Stern, but were submitted as standards in com-

petition with American standards for export work not very long ago. Since writing the paper the author has had submitted to him a style of lattice girder for export work, and he was asked if he would insist on American shops matching the same in style of design in plans that they would submit for the same bridges. The lattice girder had some of the characteristics of the plate girders described in his paper, with the added feature that the web members were to one side of the middle plane of the girder. It is needless to say that the author did not insist on the American designers following this style.

Mr. Leisner's explanation of the way the details of a bridge are made in England makes very clear the reason for their character. From men who never aspire to be anything more than detailers and whose sole training comes from the school room, be their stay there 9 or 29 years, archaic design is the most natural thing to expect. His argument that these bridges stand up and carry their load is not a weighty one. Numerous examples are on record of structures that have carried their load for 20 to 40 years and have then collapsed under their usual load.

Regarding the Euler column formula, Mr. Leisner states that this formula finds application only to columns with a slenderness ratio of more than 125. How, then, are we going to use it in a structure where the specifications expressly forbid the use of columns with a ratio exceeding 120? How would it be used "with a factor of safety of five," as allowed by the Prussian regulations, on a column whose ratio is 30? The formula gives about 320,000 lb. per sq. in. Would any sane engineer design a column of this ratio for a load of 64,000 lb. per sq. in. *safe carrying capacity*? Since all of the columns in a railroad bridge lie in the range where the Euler formula has no practical application whatever, what possible use or place has this formula in specifications for railroad bridges? Its introduction in specifications is a serious blunder made by European engineers, because the values found by it for "real" columns bear no relation whatever to the strength of the column. This formula gives the correct ultimate strength of long, slender posts, but a *good guess* is vastly nearer to the truth for short ones. This is too large a subject to discuss here, however. It is taken up at length in Chapter X of the author's book, "Steel Designing."

Mr. Stern calls attention to old bridges that need inspection. The paper does not deal with old bridges, but with the present standards, and tells how they do or should tend to make periodic inspection unnecessary. Mr. Reichmann speaks of the care with which our American bridges are guarded and inspected and how the details are kept on file. One-half hour with the plans of a certain bridge that caused a fatal wreck a short time ago ought to have been enough to "inspect" it out of existence. This is one of the structures that carried its load for more than 20 years, though it

was never safe at any time in its history. A simple clause in the specifications, requiring that the end stiffeners of a girder be placed over the shaft of the supporting column, if observed, would have avoided this wreck, and yet Mr. Reichmann would not have the manufacturer hampered by prescribing methods.

There are infinite ways by which the manufacturer could gain if he were not hampered by methods. One has only to check the details of two bridges,—one a lump sum job, the other a pound price,—to see what ramifications the thing may have. This is also an excellent way to get different lights on professional judgment. If results only were specified and methods left to the manufacturer, how could it be proven that open hearth steel is better for any special purpose than Bessemer? How could an inspector show that a casting riddled with blow-holes would not give all the desired results, particularly if these holes were filled with lead? Where would quibbling between manufacturer, inspector, and engineer have an end? What chance would there be for the manufacturer whose methods are good and proper, in competition with the one whose methods are as bad as they can be and yet productive of apparently similar results?

The uncertainty of rivets in tension has been referred to and preference for bolts expressed. While the author did not comment on this in his paper, his experience has led him to favor allowance for tension on rivet heads when properly safeguarded in the details; that is, allowing no less than four in a connection, using low units, requiring a symmetrical connection, using thick metal that will not bend, etc. The author knows of a large viaduct where the sidewalk brackets would collapse and the trusses would be wrecked if the heads should pull off four rivets in tension. This, of course, is outrageous. But the structure stands and has stood for some years, showing what tensile strength of rivets will do. Of course, rivet heads sometimes pop off. This is the result of failure to specify and watch methods, and contentment with results. If rivets are not properly heated, both in the manufacture of the rivet and in the driving of it, this result is apt to follow. Here is where an inspector with a good club in the shape of a clause specifying methods is eminently useful. To appreciate some of the advantages of rivets as opposed to bolts, one has only to be field inspector on a job a while, and to have a case where a few rivets cannot be driven and where he wants "turned bolts with washers in reamed holes" put in instead. First he orders them put in. Then he comes around, and finds that common undersized erection bolts are in the holes, and these are loose. Then he "storms," and the erector, almost with tears in his eyes, buys some machine bolts at the hardware store. At the next visit he finds these have been put in, but there were not enough to go around, and some holes were left open. On the next visit he finds bolts in all the holes but many of them are not tightened up. It is very difficult to get erectors to tighten up bolts; bolts do not have the permanence of good rivets; they can be

loosened by mischievous persons; they do not seal the metal as well as rivets. For these reasons the author prefers rivets, in general, to bolts.

The author did not express general approval of Cooper's specifications but of the system of units contained in the same. The very thing that Mr. Lacher advances as an advantage of the A. R. E. specifications is one of the chief objections that I have found to them. I find the impact method of no use whatever in investigating an existing bridge, because it *does not give the real stress in the members*. What I want to know is the actual stress in a member, what part of that stress is dead load stress, and what part is live load. This gives me a basis for judging whether the member is good or not. The recorded results of impact measurements are so discordant that instead of following any curve they look as if they were dusted from a pepper shaker. Mr. Stern, while pointing out some results that agree with the curve, himself emphasizes this irregularity. It is the roughness of track and the swaying and pounding of the load that causes the live load effect on a structure, the so-called impact, and this has nothing whatever to do with the length of the load on a structure. Live-load stress is more destructive on a structure than dead-load stress, and it should have a higher factor of safety. Parts receiving greater shock should have the maximum factor of safety. This is done in other classes of design besides structures. It is rational. Mr. Reichmann calls it rule-of-thumb and condemns it, and yet he speaks of a factor of ignorance, which he does not condemn. Engineers may as well confess that there are some things that they do not know and do not need nor want to know. The absolute strength of one little compression member, carefully nurtured and most accurately tested, cannot be predicted; how much less a large structure. The best that can be done is to adopt methods and units that are safe and at the same time not wasteful. They should further be simple of application for the purpose of avoiding errors.

There can be no question of the safety of Cooper's units. They allow 100% for impact, virtually. They assume that live load is twice as destructive on a member as dead load, in other words. This is a logical premise. The impact formula presumes that the peak stress found by observation or theory is no more destructive than the same load constantly applied. This is wrong. An oft repeated load of a certain amount may cause rupture in a member which could carry that same load as a quiescent load indefinitely. The impact method, as commonly used, is not unsafe. It is illogical. It is decidedly unsafe, however, with 26,000 lb. as the basic unit, as stated by Mr. Lacher. No structure, old or new, should be allowed to exist with stresses like that and anything less than 100% for live load impact.

If the track were perfectly smooth and the wheels perfectly true and balanced, impact formulas that take into account the length of the load would have some meaning. It would then be exactly

as though a portion of the load were shoved on the bridge and allowed to come to rest, then more load shoved on and allowed to come to rest, etc., the process being continuous. But this is so far from being the case that what little effect it may have can and should be neglected and ignored. If one will sit or stand for a while on the bottom chord of a bridge while a long train passes over it, he will learn that the whole of that train is "live" whether the bridge be long or short. I think he will concede that the load is twice as trying and destructive on the bridge while rumbling over the tracks as it is when at rest.

Such things as the relation between the speed of a train and the period of vibration of the truss, or the circumference of the driving wheel and the span or panel length, have a very marked effect on impact. How could these ever be taken into account in a formula? We cannot escape the conclusion that it is the factor of safety or of ignorance that must be looked to, to cover these and an endless number of other unknown terms.

There is only one solution to the rivet problem, that is to use low units. The units of the A. R. E. specifications are too high. When one considers the strong probabilities of rivets being loose or bad,—and this almost invariably in the most important points of a structure, the end connections,—the wisdom of using low units is apparent. The rivets that are affected by the unit values of the specifications are but a small portion of the total number in a structure. A riveted connection does not "come and go" as a member in stress, unless it is very weak, hence impact formulas or fatigue formulas need not be applied.

PROCEEDINGS OF THE SOCIETY.

MINUTES OF THE MEETINGS.

Regular Meeting, March 3, 1913.

A regular meeting of the Society (No. 815) was held Monday evening, March 3rd. The meeting was called to order at 8:20 p. m., President Reichmann presiding and with about 65 members and guests in attendance. The reading of the minutes of the preceding regular meeting was dispensed with, but the Secretary reported from the Board of Direction the following list of applicants for membership:

Carl W. Chase, Gary, Ind.
Samuel E. Stout, Gary, Ind.
James W. Pearl, Chicago.
Charles L. Weiss, Chicago.
Ray C. Yeoman, Valparaiso, Ind.
John L. Parsons, Humboldt, Iowa.
Frank M. Harshberger, Chicago.
Victor H. Bell, Valparaiso, Ind.
Paul M. LaBach, Chicago.
Mahlon J. Hammer, Chicago.
Thomas D. Mylrea, Winnipeg, Man., transfer from Junior.
Edwin C. Hall, Chicago.
Max L. Loewenberg, Chicago.
Willard E. Lofgren, Chicago.
Richard T. Logeman, Chicago.
Paul Hanson, Urbana, Ill.

Also that the following had been elected into membership:

Charles E. DeLeuw, Chicago.....Junior Member
Fred B. Money, Gary, Ind., transfer from Junior to.....Associate Member
Joseph C. Worrell, Minneapolis, transfer from Associate Member
to.....Member
Clure M. Powell, Chicago.....Associate Member
Hyman M. Shulman, W. Lafayette, Ind.....Student Member
Don E. Marsh, Glencoe, Ill.....Member
John L. McConnell, Chicago.....Member
Jesse H. Libberton, Chicago.....Associate Member

The President then introduced Mr. Paul Hanson, Engineer of the State Water Survey, who read his paper on "Improvement of Water Works Management." Discussion followed from Messrs. J. W. Alvord, Benetzette Williams, W. H. Finley, W. M. Wilson, B. J. Ashley, F. E. Davidson, B. J. Arnold, E. A. Rummler, F. E. Herdman, C. C. Saner, W. W. DeBerard, and Andrews Allen, with a closure from Mr. Hanson.

Mr. W. H. Finley was then introduced who opened a topical discussion on "The Legal Status of the Engineer," in which discussion Messrs. L. E. Cooley, F. E. Davidson, B. J. Arnold, J. W. Alvord, Andrews Allen, and W. C. Armstrong took part.

Meeting adjourned at 10:50 p. m.

Extra Meeting, March 10, 1913.

An extra meeting of the Society (No. 816)—the Bridge and Structural Section—was held Monday evening, March 10th. The meeting was called to order at 8:15, Vice-Chairman J. H. Prior presiding, and with 62 members and guests in attendance. As there was no business before the meeting, the Chairman introduced Prof. F. O. Dufour, of the University of Illinois, who read his paper "Some Experiments on Highway Bridges under Moving Loads." This was illustrated with a number of stereopticon views. Discus-

sion followed from President Reichmann and Messrs. Ernest McCullough, W. G. Langenheim, W. S. Lacher, O. F. Dalstrom, E. A. Howes, with replies and explanations from Professor Dufour.

A vote of thanks was tendered Professor Dufour for his interesting and valuable paper.

Meeting adjourned at 9:45 p. m.

Extra Meeting, March 17, 1913.

An extra meeting of the Society (No. 817)—a Smoker—was held Monday evening, March 17th, convening about 8 p. m., with nearly 200 members and guests in attendance. President Reichmann presided, and introduced Mr. W. R. Patterson, M. W. S. E., who had but lately returned from Panama, and who showed a number of lantern slides depicting the present condition and progress of the work on the Canal and Locks. Some music was furnished by a victrola that was appreciated.

Refreshments were served, together with Portland cement pipes and tobacco from the Universal Portland Cement Co., as well as cigars—a successful meeting, which adjourned about 10:30 p. m.

Extra Meeting, March 24, 1913.

An extra meeting of the Society (No. 818)—a joint meeting of the Electrical Section W. S. E. and the Chicago Section A. I. E. E.—was held Monday evening, March 24th.

The meeting was called to order at 8:25 by Mr. R. F. Schuchardt, Chairman of the Electrical Section W. S. E., who then asked President Reichmann to preside. There were about 85 members and guests in attendance. As there was no business, the President introduced Mr. Halford Erickson, Chairman of the Wisconsin Railroad Commission, who read his paper on "The Regulation of Public Utilities in Wisconsin." Discussion followed from Messrs. B. J. Arnold, E. W. Bemis, W. J. Norton, K. B. Miller, G. T. Seely, H. Almert, William B. Jackson, and B. Hoffman, with replies and explanations from Mr. Erickson.

A vote of thanks to Mr. Erickson for his valuable and interesting paper was offered, seconded by Messrs. Arnold and Schuchardt, and carried.

Meeting adjourned about 10:45 p. m.

J. H. WARDER, Secretary.

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THIS SOCIETY.

BOOK OF STANDARDS. Containing Tables and Useful Information pertaining to Tubular Goods as Manufactured by the National Tube Co., Pittsburgh, Pa. The National Tube Co., Pittsburgh, Pa., 1913. 559 pages, 4 by 6½ in., flexible leather bound. Many tables and 131 figures in text. Price \$2.00.

To an engineer or draughtsman whose work deals more or less with pipe work, this book is a very valuable manual. It has been the aim of the compiler to give all the dimensions and data pertaining to the tubular goods made by the National Tube Co., up to date. There has also been included much information on subjects related to the use of pipe and fittings. The book opens with an introduction, which gives some information as to the growth in the manufacture of iron pipe, also the methods of making the pipe, the welding, annealing, threading, inspection and testing. One product of the National Tube Co. is known as Shelby seamless steel tubes, the manufacture of which was greatly fostered in the beginning by the demands for bicycle frames. The seamless tubes are made of sizes up to 6 in. diameter and have a smooth surface. Tables are given showing the chemical analysis and physical properties of the metal (steel) in these tubes. Tables of properties of pipe are given on pages 22 to 37 showing diameters, inside and

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outside, weight per foot, number of threads per inch, and the couplings. These dimensions vary with different kinds of pipe and tubing but are all shown and are of value to the draughtsman and engineer.

Locomotive boiler tubes are an important branch of iron pipe manufacture, and tables are given showing properties of such tubing. These tables include such data as length of tube per square foot of surface, **internal and external**, according to the nominal diameter of the tubing, the internal and external diameters and weight per lineal foot, and the square feet of (internal and external) surface per lineal foot. This information is of value to the designer and draughtsman who have occasion to use tubes in a boiler, heater or condenser. Corresponding tables are also presented pertaining to ordinary iron (or steel) pipe, such as is used for conveyance of liquids or gases.

There are many other tables of valuable information and data pertaining to varieties of tubing, wall casing, etc. Cuts are shown of various forms and dimensions of pipe couplings, whether for ordinary steam or gas piping or wall casing and other sorts of pipes. The book contains several pages of standard specifications for various kinds of pipe and tubing. One line of trade which has been developed within a comparatively few years is that of tubular poles, for covering electric lines, lamps, signals, etc. These are made of two or more sections of pipes of different diameters, fitted together to get the best disposition of the metal (the strength of the pole) for the service demanded. These poles range from 22 to 40 ft. in length.

There are many matters of engineering interest introduced in the text, which do not pertain specifically to tubing, but are of interest to engineers as bearing on problems more or less connected with the use of tubing and pipes. The Briggs Standard Pipe Threads, physical properties of carbonic acid, thermal expansion of iron and steel tubes, strength of tubes, pipes and cylinders under internal fluid pressure, with various formulæ, diagrams and tables, also the collapsing pressures of tubes, with tables and diagrams, are given. Several pages are given with tables, formulæ, etc. of the strength and other properties of pipe or tubes when used as column, beams, etc., in structures.

There is much information of value to engineers, conveniently arranged in this book, about water, its flow in pipes with formula, and its measurement, water power, incrustation, contents of tanks, discharge through pipes, etc. Similarly the properties of gases, the flow through pipes, etc., are given and also that of steam, its flow through pipes, etc. Finally there are tables of weights and measures, the ordinary and metric, and conversion tables for these and for temperatures, followed by a glossary of terms and definitions used in the pipe and fitting trade, amounting to 40 pages, and concluding with a very full and complete index to the contents of the book. The making of the book in its handsome leather binding and clear typography is very good, and the price is only \$2.00.

RAILROAD CONSTRUCTION, by Prof. Chas. L. Crandall and Asst. Prof. Fred A. Barnes, of Cornell University, New York, 1913. McGraw-Hill Book Co., pp. 321, 6 by 9 in. with 81 illustrations; cloth bound. Price \$3.00.

This book has been developed from a series of notes prepared several years ago for class use in the course of Railway Engineering at Cornell University. The earlier form was prepared by some duplicative process such as has often been used by instructors for their classes. Experience and service demonstrated the usefulness of such instruction notes to their own classes, and presumably they would be valuable to the corresponding classes at other engineering schools. When this time comes, it is incumbent upon the author or authors to put their work in a more permanent and accessible form for the benefit of "The Profession." This book is a case in point, and includes an introductory chapter followed by Earth Work, Rock Excavation, Tunneling, Masonry, Foundations, Culvert and Bridge Masonry, Trestles and Bridges, Track Material, and Roadbed, and concluding with Estimates and Records. Of course, as the field covered by the

book is a big one, it naturally follows that some matters cannot be as thoroughly expounded as in a special treatise on that subject, but the book furnishes a valuable summary of methods of handling railroad construction. There are some good illustrations through the book, particularly in the chapters pertaining to Tunnel Work, Masonry and Bridge Work. Cost data are introduced freely, which is a valuable feature in the book. Another feature which should be of great usefulness to the student reader is the notes, bibliographical, at the end of each chapter, which will advise the reader where he can find additional reading matter for his education. These bibliographical notes include articles in various engineering papers as well as the names of text-books and their authors. Taken all in all, the reviewer's opinion is that the book is a useful one and worthy of a place in the library of young engineers now engaged in or expecting to be occupied with Railroad Construction.

HAND BOOK OF RAILROAD EXPENSES, by J. Shirley Eaton, at one time Statistician of the Lehigh Valley Railroad, New York, 1913. McGraw-Hill Book Co., pp. 560, 5 by 7½ in., flexible leather binding. Price \$3.00.

An earlier book by this author, "Railroad Operations—How to Know Them," which was of much value when first published, has become almost obsolete under later and changed conditions, and sundry rulings of the Interstate Commerce Commission. In this new book the author gives an exposition of the various items under operating expenses and shows when and why these charges should be made. The Interstate Commerce Commission has prepared classifications of Operating Expenses, Income Account, Balance Sheet, etc., and the text of these classifications and instructions is given in this book. The book is of particular value to the higher officials of railway service, including the auditors and higher accountants, as it is they who formulate the orders governing the bookkeeping of the road, but it can be read with profit by men in lower grades of service that they may understand the basis which governs the question as to what account an expense should be charged. The operations of the Interstate Commerce Commission have been very beneficial to the industrial world by their rulings, which require the keeping of accounts of the railroads in a uniform manner, that the true financial status of the corporation may be so much better known.

Considerable space in the book, more than 150 pages, is given to an index to account numbers and case numbers, which refer to certain accounting bulletins issued by the Interstate Commerce Commission. This feature alone makes the book of value and the author is to be congratulated upon so ably meeting this need.

REGULATION, VALUATION AND DEPRECIATION OF PUBLIC UTILITIES, by Samuel S. Wyer, M. E., 1913, Columbus, Ohio. The Sears and Simpson Co., pp. 313, 6 by 9 in., 47 figures and 15 tables, full leather flexible binding. Price \$5.00.

This book consists of sixteen chapters, as follows: 1, The Public and the Public Utility. 2, Fundamental Definitions. 3, Economics of Utility Problems. 4, Governmental Power to Regulate Utilities. 5, Protection of Utilities from Adverse Regulation. 6, Requirements of Regulations. 7, Relief from Oppressive Regulation. 8, Depreciation. 9, Electrolysis as a form of Depreciation. 10, Legal Status of Electrolysis. 11, Valuation. 12, Going Value and Going Concern Value of Utilities. 13, Principles Governing Cost of Utility Service. 14, Engineering Data Pertaining to Utility Regulation. Valuation and Depreciation Problems. 15, Reference Data. 16, Selected Bibliography.

The author has gathered in this handy volume a great deal of valuable information for those in any wise concerned with Public Utilities. The titles of some chapters of the book indicate that the book is not intended as a biased expression of personal opinion in favor of or against Public Utilities, but that the desire of the author is to present basic principles

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which need to be understood, on taking part in a discussion of a controversy relating to some public utility.

The arrangement of the text-matter in some particulars is a little out of the ordinary, yet in a way that has advantages. The paragraphs are numbered consecutively, which makes cross references readily available, and through the book there are frequent references to some other paragraph which has a bearing on the particular topic under consideration. The Selected Bibliography in Chapter 16 has a reference number to each item whether this be books, articles in technical literature, or Court Reports, and throughout the text these numbers, as references to authorities, are used freely. The index at the end of the book seems to be very complete.

ENGINEERING OF SHOPS AND FACTORIES, Henry Grattan Tyrrell, New York, 1912. McGraw-Hill Book Co. Cloth bound. 399 pages, 6¼ by 9½ in. with bibliography and index, 175 illustrations and many tables. Price \$4.00.

The book opens with a well-written preface and introduction and then in Chapter I discusses the plans, by whom to be made, cost of engineering services, contracts for engineering services, etc. These preliminary but necessary matters being concluded, then comes the Manufacturing District and the principles which should govern the choice of location, character of manufacture, needs of shipping facilities, selection of lot, etc. The economics of factory construction naturally follows, which is dependent upon methods of manufacture and on management, processes, and a sequential arrangement of machines, proportionate areas of floors to the work that is to be done there, the receiving of raw material and good shipping facilities, etc. These matters having been more or less completely settled in advance, the Preliminary Design is in order, which considers the plot of ground to be secured, the size, shape and location of the several buildings, etc. Other chapters follow enlarging on these points, the aesthetic treatment and the design in whole and detail of the structures, the material to be used having its influences. Steel frames, with or without brick, slow burning timber construction, the using of concrete, plain and reinforced, are all considered and discussed.

One chapter is given to the discussion of Special Buildings, as Machine Shop, Foundries, Car Sheds, Cotton Mills, Power Houses, etc. Over the greater part of the United States where manufacturing buildings now exist or are likely to be built, it is necessary to make provision for heating and ventilation, and this matter is duly presented in two or three chapters. Factory Lighting is also a matter of considerable importance and is considered in some 25 pages of the book. The drainage, water supply and water storage, sanitary matters, fire protection, are all matters of economical importance and are duly considered by the author. The book also contains a chapter on estimating, and costs of construction, with several pages of typical estimates and bids.

The bibliography of 5 or 6 pages which follows the text and precedes the final index is of value to those who wish to make further readings in this line of work.

Altogether it is the reviewer's opinion that this work has decided merit and the study of which would be of benefit to many so-called *Industrial Engineers*.

AN OUTLINE OF THE METALLURGY OF IRON AND STEEL, A. Humboldt Sexton, of the Royal Technical College, Glasgow, and J. S. G. Primrose, Member Iron and Steel Institute, London. The Scientific Publishing Co., Manchester, England, 572 pages, 5½ by 8½ in., including index, 273 illustrations, cloth bound. Price 12/6 net.

There is no date given to this book, but as it is the second edition it is presumably of recent publication. The book consists of 44 chapters and an appendix. The first or introductory chapter tells of the physical and chemical characteristics of the metal, whether "soft," *i. e.*, free from those

hardeners found in various grades of steel which assist in making the iron more permeable to magnetic influences, or hard iron, when the iron contains various alloys of carbon, manganese and the like, a necessary condition in steels, and which make the iron less permeable to magnetic influences, and consequently the iron is more retentive of magnetism.

In Chapter II consideration is given to iron in nature, the various ores or compounds, their distribution over the earth, impurities in the ores and their values, their classification and the output of iron ores.

In Part II, Chapter III, pig iron is considered at some detail, the grading of such and their greater or less value for sundry metallurgical operations.

Blast furnace operations are described in Chapters IV to XII of over 100 pages. The chemistry of the reaction is explained, and the temperature at various zones of the furnace is shown. Illustrations explain the shape of the blast furnace, the internal diameter at various points, and the reasons for these are stated. Various accessories are listed and described, such as the hopper at the furnace top and its closing bell, the down-comer which provides for the collection and delivery of the inflammable gases produced in the furnace and which are of considerable thermal value. In earlier practice these gases were consumed under boilers for steam generation; later practice utilizes these gases in gas engines for power generation.

The casting of the pigs and the handling of them is of importance and many improvements have been devised to lessen the manual labor of this work. The elevation of the stock, ore, fuel and flux, to the top of the furnace is of much importance and many improvements have been made in this matter. The air supply, the pressure of the blast, etc., are also of great importance and under modern conditions the blowing engines are of mammoth proportions. This air is pre-heated before putting it into the furnace, and hot blast stoves of various forms have been devised for this purpose. A large amount of the blast furnace gases is utilized in heating the air prior to its delivery into the furnace. Blast furnace practice varies in different localities, influenced by the character of the ore, fuel and other matters.

Various by-products are the result of furnace operations, the most notable being the slag, which is varied in its chemical composition, depending on the working of the furnaces and the chemical and physical characteristics of the burden. This slag is a silicate of lime and alumina and generally carries more or less iron, manganese, sulphur, phosphorus, etc., depending on the constituents of the ore and flux. Part of the gases frequently carry some hydrocarbons, tarry matters and also ammonia compounds. These are sometimes collected and utilized.

In Chapter XIV is the History of Cast Iron, which is of interest. Following this is a chapter treating on the foundry, in which is remelted the pig iron so it may be cast into various desired forms. The selection of the pig metal and compounding with other brands is of value, the charging of the cupola, the proportioning of the fuel to the charge, the intensity of the blast, the preparation of the moulds into which the melted iron is run, all these are important matters and are indicated more or less in this chapter.

Part III, Chapter XVI, takes up the subject of malleable iron, which includes steel of various qualities as well as wrought iron and occupies some twenty chapters of over 200 pages. This includes descriptions of the Bessemer process and the Siemens open hearth process, whether basic or acid in its character. Other chapters describe various features of working the metal, the heat treatment, and results obtained; the testing of iron and steel for physical properties, the micro-structure of iron and steel, etc.

Though the book is thoroughly English and in some particulars does not seem to be entirely up to date in the metallurgical processes, yet it possesses a decided value to the casual reader as well as the student, as showing what is English practice and which is also applicable, in many particulars, to the iron industry in this country.

LIBRARY NOTES

The Library Committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts, the following publications have been received:

MISCELLANEOUS GIFTS.

- McGraw-Hill Book Co.:
Railroad Construction, Crandall and Barnes. Cloth.
- W. F. Goltra, Cleveland, Ohio:
Some Facts About Treating Railroad Ties, Goltra. Pam.
- Chicago Portland Cement Co.:
Concrete Builder, Vol. I, No. I, January, 1913. Pam.
- National Tube Co.:
Book of Standards. Leather.
- Hanson-Bellows Co.:
A Souvenir Guide to Chicago. Pam.
- Ralph Modjeski, M. W. S. E.:
Report on Proposed Bridge Across the Columbia River at Portland, Ore. Pam.
- Henry A. Gardner:
Notes on the Formation and Inhibition of Mildew in Paints. Pam.
- Sanderson & Porter:
The Jordan River Power Development. Pam.
- The Macmillan Co.:
Electricity and Magnetism, Hough & Boehm. Cloth.
- Doubleday, Page & Co.:
The Stock Exchange from Within, Van Antwerp. Cloth.
- McGraw-Hill Book Co.:
Handbook of Railway Expenses, J. Shirley Eaton. Leather.
- S. S. Wyer, Columbus, Ohio:
Regulation, Valuation, and Depreciation of Public Utilities, Wyer. Leather.
- John W. Alvord, M. W. S. E.:
Report on Improved Water Supply for Oklahoma City, Okla., by Hiram Phillips, John W. Alvord, and J. W. Billingsley. Pam.
- Ohio State University:
A Memorial, "Stillman W. Robinson." Cloth.
- E. E. R. Tratman, M. W. S. E.:
Annual Report of the Director of the Mint, 1902. Cloth.
36th Annual Report Department of Public Works, Chicago. Cloth.
Rating Locomotives, H. L. Cole. Cloth.
The Story of Rapid Transit, Beckles Willson. Cloth.
Synopsis of the Patent Laws of the World, John P. O'Donnell. Leather.
Surveying Manual, Pence & Ketchum. Leather.
Tube, Train, Tram, and Car, A. H. Beavan. Cloth.
American Railway Shop Systems, Walter G. Berg. Cloth.
Drill Work; Methods and Costs, R. R. Sanderson. Cloth.
Transactions, Commonwealth Club of California, 1912. Pam.
Production and Use of Petroleum in California, by State Mining Bureau, 1904. Pam.

GOVERNMENT PUBLICATIONS.

- Isthmian Canal Commission:
Panama Traffic and Tolls, Report by E. R. Johnson. Cloth.
- Library of Congress:
Report, 1912. Cloth.

- Superintendent of Documents:
Annual Report, Chief of Engineers, 1912, Parts I, II and III. Cloth.
- Smithsonian Institution:
Annual Report, 1911. Cloth.
- U. S. Reclamation Service:
Eleventh Annual Report, 1911-12. Cloth.
- Isthmian Canal Commission:
Official Handbook of the Panama Canal, 1913. Pam.
- Commissioner of Corporations:
Transportation by Water in the United States, Part IV. Pam.
- U. S. Bureau of Mines:
Second Annual Report of Director, 1912. Pam.
- U. S. Geological Survey:
Monograph No. 51, Cambrian Brachiopoda. 2 Cloth.
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MEMBERSHIP

Additions.

DeLeuw, Charles E., Chicago.....	Junior	Member
Libberton, Jesse H., Chicago.....	Associate	Member
Marsh, Don E., Glencoe, Ill.....	Member	
McConnell, John L., Chicago.....	Member	
Money, Fred B., Gary, Ind., transferred to.....	Associate	Member
Powell, Clure M., Chicago	Associate	Member
Shulman, Hyman M., W. Lafayette, Ind.....	Student	Member
Worrell, James C., Minneapolis, Minn., transferred to....		Member

Deaths.

CRISSEY, J. W., March 7, 1913.

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No. 4

THE CAUSE OF FLOODS AND THE FACTORS THAT INFLUENCE THEIR INTENSITY

DANIEL W. MEAD, M. W. S. E.

Presented June 12, 1912.

In my remarks this evening I shall discuss the cause of floods, and shall point out some of the reasons for the variation that occurs in the magnitude of floods on different rivers, and some of the causes that result in the differences in the magnitude of floods that occur at different times on the same river. I shall not endeavor to lay down any rule, nor establish any general law that can be applied to the very complicated question of the estimate of maximum flood intensities. I believe it will be impossible, without many years of observations on many streams, if at all, to establish a general law for maximum flood heights or for flood volumes, that can be applied in any general sense. The reason for this belief will, I think, be made clear by some of the facts that I shall call to your attention.

The floods in the rivers of the United States are causing annually the loss of many lives, and of property to the value of hundreds of thousands of dollars. As the country has developed, and as the lands along the rivers have become thickly settled, the damage caused by floods has come to be very serious, and the question of flood prevention, flood alleviation, and flood protection are questions that the engineer is frequently called upon to consider.

Some of the results of the floods that have occurred in Wisconsin during the last year, may give an indication of the serious nature of these flood damages, and add, perhaps, more point to the later discussion which will involve the questions of the causes of floods and their modifications by local conditions.

THE FLOOD OF OCTOBER, 1911—IN WISCONSIN.

In October, 1911, there were heavy rainfalls in northern Wisconsin, that covered a portion of the valley of the upper Wisconsin River and of the Black River, and gave rise to floods of considerable magnitude on both of these streams, resulting in considerable damage and destruction of property.

The Rothschild dam on the Wisconsin River, about six miles
April, 1913

below Wausau, was constructed a few years ago. Figure 1 shows the dam before the flood. The dam is a concrete structure built on a pile foundation in sand and gravel, having ten Tainter gates and a short spillway divided into two bays, the total spillway being about 100 ft. long. The spillway level, and consequently the low head water above the dam, is only 4 or 5 ft. below the top of a low dike which protects the mill property on the east side of the river. The mill was constructed, I understand, at an expense of over \$1,000,000. The Tainter gates when available had, I think, ample flood capacity. The original apron was constructed of concrete slabs resting on the sand and without, I understand, any sheet piling or other protection at the toe, the apron being 100 ft. or more in length. At

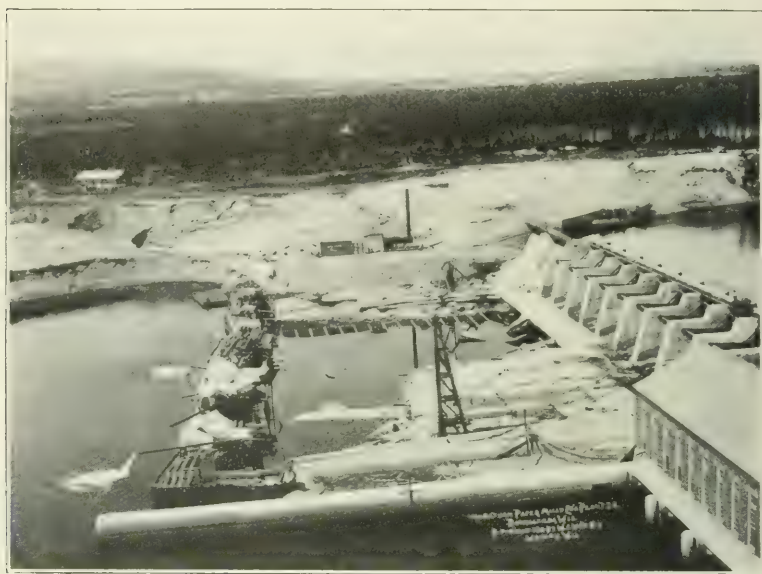


Fig. 1. Rothschild Dam on Wisconsin River Before the Flood.

the time this view was taken before the flood, repairs were being made to the apron, which repairs consisted in placing rock-filled cribs which were afterwards to be covered by timbers.

There are a great many logs still floated on the upper Wisconsin River, and at the time of the flood there were a great many logs held by a boom above the Rothschild dam. At the beginning of the flood it was not desirable to open the Tainter gates on account of the construction work on the apron below the dam. An attempt was made to pass as much water as possible through the hydraulic plant which could carry only a comparatively small amount. The spillway 100 ft. in length could take but a limited quantity, and the water rose and flowed over the dike above the dam, injuring

and threatening the destruction of the mill property. Finally, the Tainter gates were opened. The rise of the water had caught the boom on the top of the boom piers to which they were anchored, and as the water was drawn down by the opening of the Tainter gates the logs escaped under the boom and clogged up the narrow gateway, as shown in Fig. 2. In order to save the mill property, which was thus left the weakest line of attack for the flood, a channel around the west end of the dam was started, through which the river was diverted, washing out a new channel 200 ft. or more in width, and of considerable depth in the sand and gravel.

One of the losses which perhaps should have been anticipated was due to the submergence of the power plant from the tailwater.



Fig. 2. Rothschild Dam, Showing the Clogging of Tainter Gates and Submergence of Power House During the Flood.

(Fig. 2.) This was perhaps partially due to the clogging of the channel below the dam by sand and gravel, but the floor of the station was undoubtedly constructed too low. The accident to the gates was of a rather unusual character, and one which would not readily be anticipated. The loss was quite large, aggregating, I understand, several hundred thousand dollars.

The passage of $14\frac{1}{2}$ ft. of water over the Kilbourn dam is shown in Fig. 3. Here there is no logging in the stream and little danger of the gateways clogging. There was no serious trouble at this plant, although the apron was somewhat damaged by the flood. The flood rose about 17 ft. at the Kilbourn hydro-electric

plant (Fig. 4) which had, however, been anticipated, and a flood of several feet greater height could have occurred without damage. The machinery in this plant is placed below the flood water level, but was not submerged because it is placed in a concrete pit (Fig. 5) and the plant was able to run during the flood, although, on account of the reduction in head, the output was comparatively small.

The greatest loss that occurred in Wisconsin on any one stream during the October floods of 1911 occurred on the Black River. The first casualty was the failure of the earth dike section of the Dells reservoir dam. The failure of this reservoir resulted in the overtopping of the earth section of the reservoir at Hatfield, about $4\frac{1}{2}$ miles below, and the water from these reservoirs, together with the normal flood of the Black River sweeping down on the city



Fig. 3. Kilbourn Dam, Showing $14\frac{1}{2}$ -Foot Flood Passing the Crest.

of Black River Falls, caused great damage in that city. The Dells reservoir was a reservoir for storing water for power purposes, containing about 10,000 acre feet. The reservoir dam consisted of a concrete section and spillway on the east side, and an earthen dike with a concrete core wall on the west side. There were some small gates in the concrete section used to let the water out for use in the power plant below, but too small to be useful in passing floods. The Hatfield dam consisted of a concrete spillway about 50 ft. in height, on both sides of which is an earth embankment. The spillway which was some 490 ft. long was adequate for any normal flood on the river, and passed about 12 ft. of water before the east embankment was overtopped and broke. The 490 ft. spillway was somewhat obstructed, however, by vertical steel pieces for



Fig. 4. Power House at Kilbourn, With 17-Ft. Rise in the Wisconsin River.

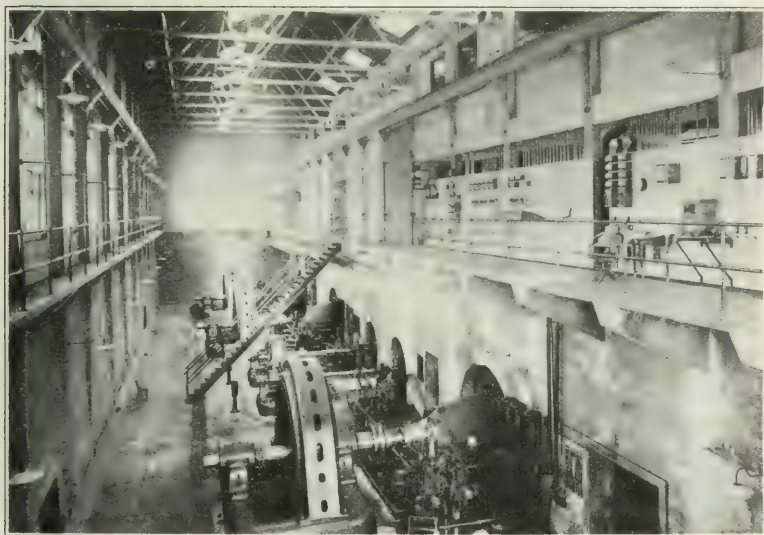


Fig. 5. Interior of Power House, Protected From High Water by Method of Construction.

holding the flashboards, and by floating material caught thereby. The flood waters, when they finally passed over the earth section, washed out 500 ft. of the embankment and about the same amount of the Green Bay & Western road which crossed the Black River at this point.

The break at the Dells dam (Fig. 6) was occasioned by the overtopping of the earth dike, due to spillway capacity inadequate to pass the flood waters. This was aggravated somewhat by drift caught in the flashboard supports. The view across the break shows, in general, the nature of the concrete core wall. The work seemed well done. The concrete section was left intact, but the earthwork with its core wall, which was well constructed, was destroyed, as a matter of course, under overflow conditions.



Fig. 6. Break in the Dells Dam on the Black River, Looking Upstream.

A view of the destroyed earth section at Hatfield, taken some time after the flood, is shown in Fig. 7. The Hatfield dam is at this point about twelve miles above the city of Black River Falls. The combined natural and reservoir flood came down on Black River Falls with disastrous effect. The conditions there were very unfortunate. Figure 8 will illustrate very well some of the conditions that were prevailing at this point before the flood. The figure shows the dam at Black River Falls during the flood of June, 1911. The June flood carried, as nearly as I have been able to determine, about 10,000 cu. ft. per second, and you will notice that the spillway was filled, and in fact, water was passing over the abutments on both sides. My calculations lead me to believe that a normal flood flow of about 40,000 cu. ft. per second must be expected at

Black River Falls under extreme conditions, and without considering the breaking of reservoirs. Here was a dam that was built as late as 1909, and yet had only one-fourth of the capacity necessary for the maximum normal flood. This was the condition that we have since been obliged to remedy by blowing out the entire construction shown in Fig 8, and replacing it with a structure consisting of a series of Tainter gates clear across the channel that will open practically down to the bed of the stream.

The north end of the dam early in the flood of October 15, 1911, is shown in Fig. 9. The power house was already submerged and the flood passing over the north abutment was already beginning to cut away the earth from below the north end of the dam. The north abutment simply entered a natural bank of earth but did



Fig. 7. Break in the Earth Embankment at the Hatfield Dam, After the October Flood, 1911.

not reach rock. A little later the river cut entirely through this point and came down on the city.

A view of the flood entering the city (Fig. 10) shows a three-story hotel with a portion of its walls just falling into the river. The buildings in the business portion of the city, resting on sand foundation, simply melted into the water and disappeared, and the flood destroyed not only the buildings themselves, and the foundations, but the land was entirely washed away for about two blocks in width and for several blocks in length. The wooden mill building which rested on a rock foundation was not seriously injured. Perhaps the best understanding of the extent of the damage can be seen from Figs. 11 and 12, showing the city before and after the flood, and from the map (Fig. 13).

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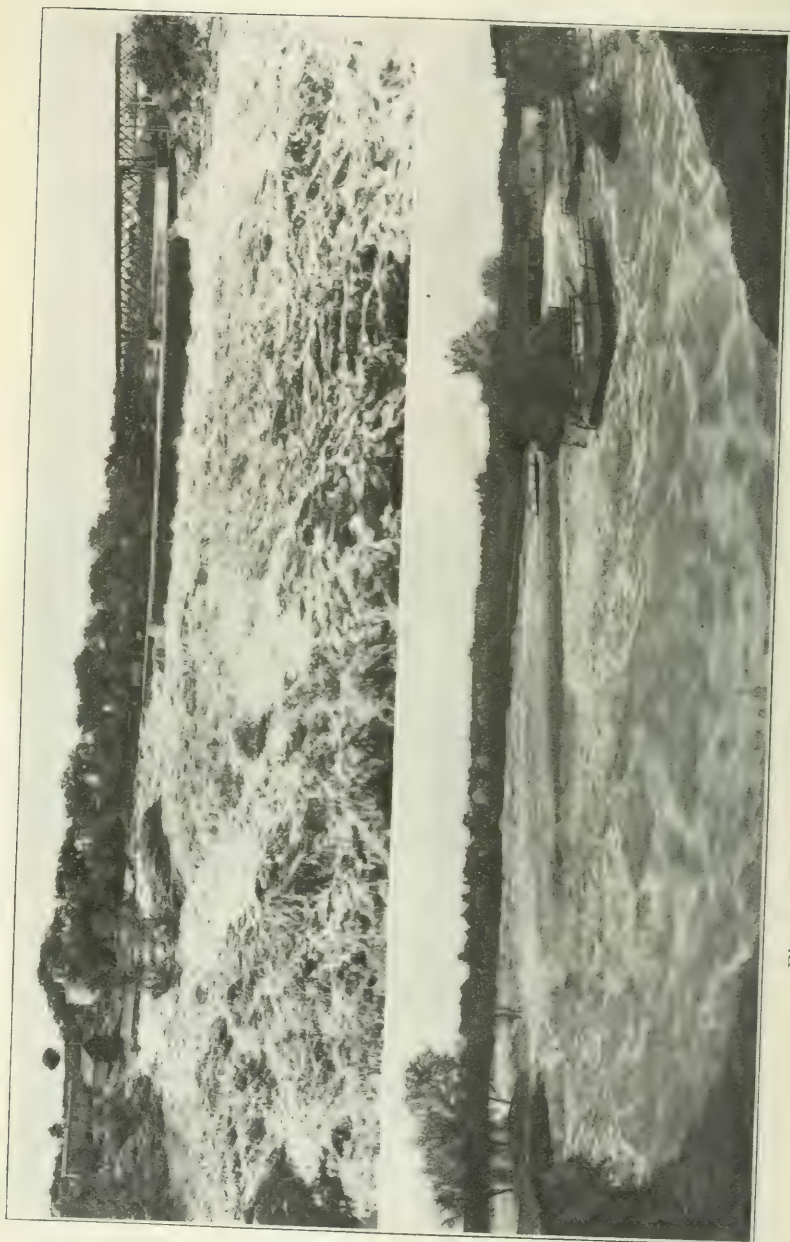


Fig. 8. (Upper) Black River Falls During the June Flood, 1911.
Fig. 9. (Lower) North End of Dam Early in the October Flood, 1911.

The question of responsibility for damages, such as are illustrated by some of the figures previously shown, naturally arises and should receive careful consideration. While this cannot be well defined and differs in almost every instance, still there are certain fundamental factors upon which little difference of opinion is possible. In the first place, there is need of much more information on the subject than is now available. Additional information cannot be gathered by individuals except to a limited extent. The extended observations and data needed for the systematic study of this subject must be gathered by either federal or state aid.

The United States Geological Survey has been doing some very valuable work in stream-flow measurements and observations, but this work is very limited, and in Wisconsin has been discon-



Fig. 10. Flood of October, 1911, Entering the City of Black River Falls.

tinued. The amount of work done in Wisconsin is almost insignificant in view of the amount of information which is needed to place this whole subject on the basis that will result in safe and intelligent design and construction. The work of stream measurement must be done largely by state aid, for no private individuals or corporations have sufficient interests, except at a few scattered localities, to maintain gaging stations. I believe that state officials and legislatures should be urged by engineers and others interested in these matters (and there are few people living or having property interests along streams, who are not, or should not be interested in this matter), to take active measures towards the establishment of gaging stations on a variety of streams, so that the information secured will give sufficient knowledge on which to base

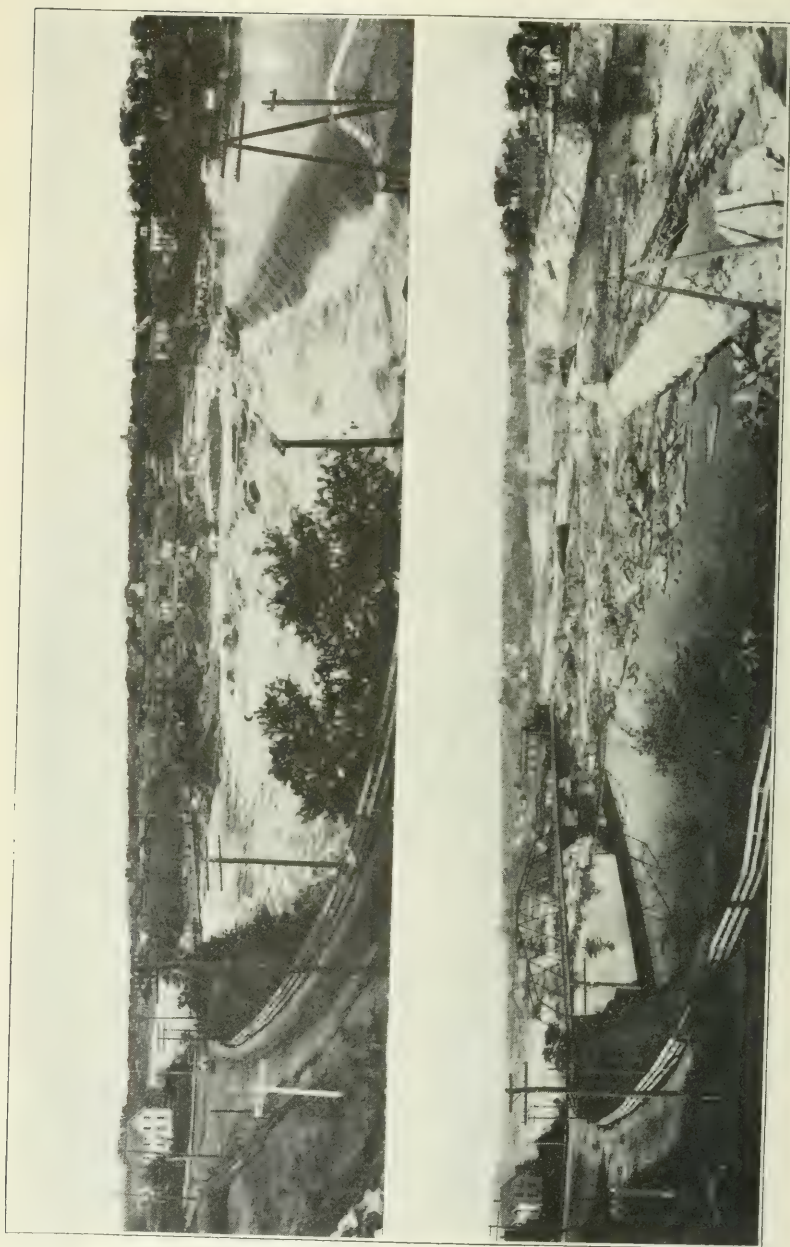


Fig. 11. (Upper) Black River Falls Before the Flood.
Fig. 12. (Lower) The Same After the Flood (October, 1911)

intelligent efforts for the solution of these problems in a safe and economical manner. This information is needed, not so much for the water power interests, as for the safety of the people of the state and all of the property interests that are concentrated along the river valleys.

The engineer, undoubtedly, needs a great deal more information than is now available, but there is a good deal of information which can be obtained at present if the engineer will take the trouble and make the necessary investigations to ascertain it. In many cases there is no evidence that sufficient attention has been given even to the data that are now available. The engineer must become interested in this subject sufficiently to investigate it, and he

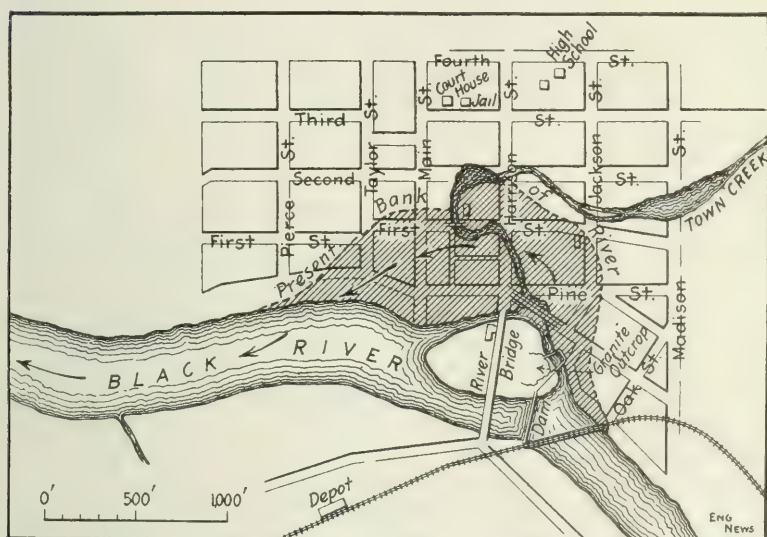


FIG. 13 SKETCH MAP OF ERODED AREA OF BLACK RIVER FALLS.

should use such information as he has to secure proper legislation, both for securing information by state aid and for the passage of such laws as will make, at least, a general supervision of this whole subject a state matter in order to protect the public from ill-advised and immature plans.

I do not believe that accidents or losses can be eliminated by state supervision and inspection, but I do think considerable can be accomplished. I am satisfied that if plans and specifications are required to be sent to a state office for approval, if there is ever a suspicion that the plans will be examined carefully, more thought will be put into the general study of the problems, and in the preparation of intelligent plans, and better results will accrue even from

very limited state inspection. Much more will be accomplished if intelligent state inspection can be secured.

The flood question is not a new one. It is as old as the science of hydraulic engineering, and has attracted the attention of engineers for years. Many attempts have been made to solve the problem of maximum flood flow, and a great many formulae have been suggested to determine the flood flow and the ordinary flow of streams. If the various flood run-off formulae are platted it will be found that deductions from them are very far apart, and consequently they must necessarily lead to very erroneous results unless they are used intelligently. One of the greatest dangers in the estimation of run-off comes from the use of these formulae. Their value is very great, but their great value is only reached through intelligent use. The engineer who attempts to use a run-off formula without knowing all about its derivation, and whether it applies to the particular area he has under consideration, is sure to invite trouble for his clients and himself. Many estimates of flood flow are made in this manner. Somebody's formula is used and it is assumed that the problem is solved, until the normal maximum flood demonstrates that the formula does not apply to the problem at hand.

Hydrographs of five different rivers, all in Wisconsin or Michigan, are shown in Fig. 14. These hydrographs are drawn to the same relative scale, and show the discharge in cubic feet per second per square mile of the drainage area of the stream in question. The flows, therefore, are comparative except as influenced by area, which differs considerably as shown. In a general way the rainfall conditions on these drainage areas are fairly comparative in total annual amount, although its occurrence and distribution varies more or less. The different conditions of average and storm flow on these various streams are due partially to the difference in occurrence of rainfall, but more particularly to the difference in other conditions on the drainage areas, which will be discussed later. Please note in this diagram the flow of the Black River in the flood of 1905, one of the largest floods on record on that river, in which there was a discharge of some 32 or 33 cu. ft. per sec. per square mile at Neillsville. Note also that on the Wisconsin River at Necedah the maximum discharge was apparently 16 or 17 cu. ft. per sec. per square mile. I think, however, the flow shown at Necedah is somewhat too high. The Menominee River near Iron Mountain, Michigan, is shown to be a stream of comparatively low flood flow. The Rock River at Rockton has floods of still less magnitude, while the Manistee River in Michigan has flood flows of only about 3 cu. ft. per sec. per square mile.

Here are shown five streams in adjacent territory, which are quite different in flood intensity under rainfall conditions, and which, so far as total amount of annual rainfall is concerned, are not very different. The Manistee River has about the most uniform flow of any stream with which I am familiar. I believe the

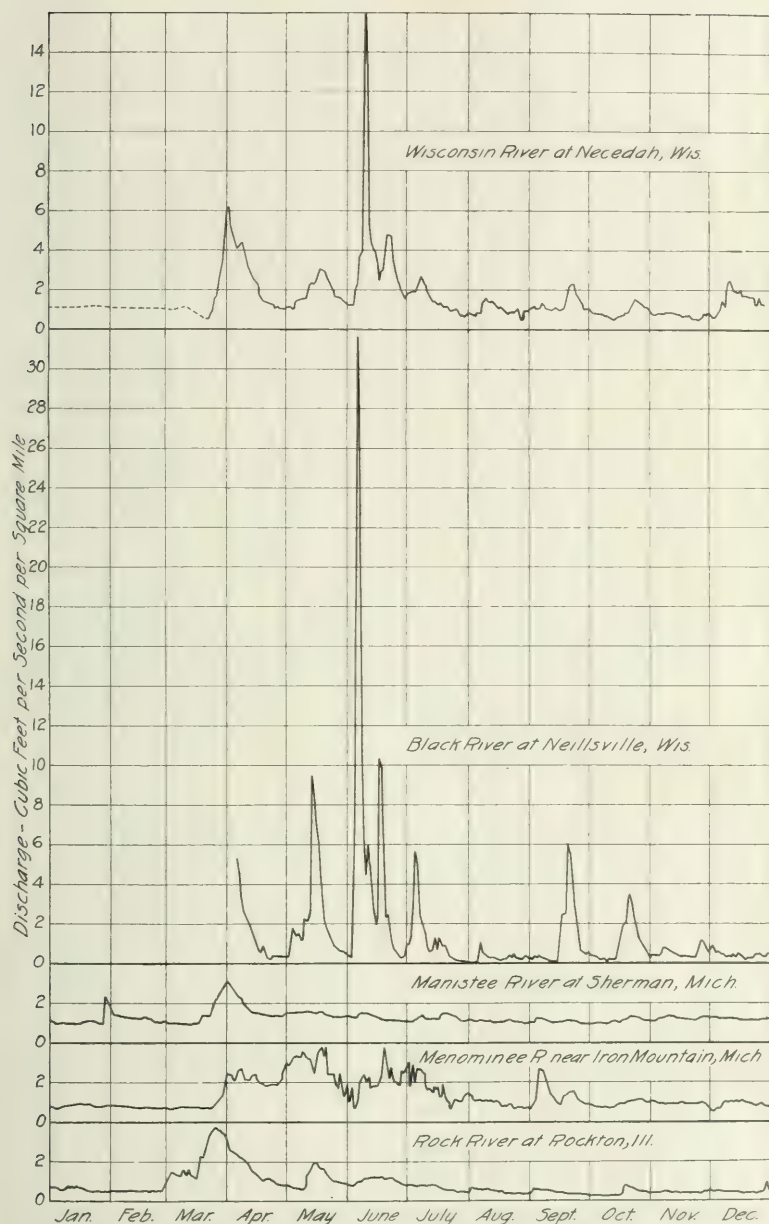


Fig. 14. Hydrographs of Various Rivers in Wisconsin and Michigan.

percentage of variation of flow in the St. Lawrence River, which is fed from the immense reservoirs of the Great Lakes, is equal to, or greater than the percentage of variation between the low water and flood flow of the Manistee River. The Rock River has a somewhat greater flood flow than the Manistee, and a much less low-water flow. The Menominee River has greater floods and higher low-water flows than the Rock River. The Wisconsin River has still higher floods but about the same low-water flow as the Menominee, and the Black River has the greatest percentage of variations in flow of any river of any considerable size in Wisconsin or Michigan with which I am familiar. The flow of the Rock River in cubic feet per second per square mile is, in general, about one-half that of the Wisconsin River, both in low water and high water. Taking into account the size of the drainage areas, I should say that the Black River has at least 50% greater flood flow than the Wisconsin, while the average flow of the Black River is somewhat less than the average flow of the Wisconsin River. These five rivers are in territory included within a radius of a few hundred miles. They are under rainfall and temperature conditions that are quite similar. What, then, is the reason for this very great variation in their ordinary and flood flows?

In order to give a hasty, yet fairly clear idea of the underlying causes of these differences in river flow, I wish to picture to you for a moment, a conception of the conditions of two ideal streams, one of which will represent the conditions of a stream with the maximum flood flow and the greatest variations between high and low water, and the other the conditions surrounding a stream with minimum floods and the greatest uniformity of flow.

Conditions for Maximum Flood Flow.

For the conditions of a stream with maximum floods we must picture a bare rocky drainage area with very steep, abrupt, rocky, slopes which are largely impervious. The drainage area will be comparatively small so that storms of maximum intensity will practically cover the entire area. The rains which fall on a drainage area of this type would run off quickly. There will be little absorption. There would be little on the drainage area to prevent the rapid descent of the rain water to the channel. Evaporation would be comparatively small because of the rapid movement of the water, and the storm water would therefore rush off in a maximum flood, after which the flow would soon cease entirely if there is no storage assumed to keep up a low water flow.

Conditions for Minimum Flood Flow.

Now let us picture a drainage of similar area, but with rock valley filled with perhaps a hundred feet or more of sand and gravel. The steep slopes of the former valley are cut down and covered with sandy loam. This drainage area has low slopes with a deep sandy soil. It becomes essentially a sandy plain through

which the stream slowly meanders, and the conditions which thus obtain result in the greatest uniformity of flow and in minimum flood conditions. The rainfall in this valley, even when of the greatest intensity, falling on the flat slopes, moves slowly in the direction of the stream; but the water seeps rapidly into the sand, passes down to the ground water, and then flows slowly in the general direction of the stream channel. Under these conditions it must be a most intense rain which could produce any surface run-off except in the channel of the stream itself.

In many parts of Michigan, within a few minutes after a hard rainstorm, one can go out into the sands of the drainage area dry shod. The grass and foliage may be wet, but from the sand soil itself the rainfall has practically disappeared, a condition which I think prevails on the drainage area of the Manistee River, and which is, I believe, the leading cause of its uniform flow.

MODIFICATIONS IN FLOW.

I present the condition on these two streams as above outlined, as my ideal of the conditions leading to maximum and minimum conditions of flood flows. Any modifications of these conditions will tend to modify the floods. On neither of the ideal streams we have considered was there any vegetation. With sufficient soil on the rocky drainage area so that grass and trees gain root, the intensity of floods will begin to be modified, for free flow will be in a measure prevented. The soil and the vegetation will tend to retard and retain, to a certain extent, the storm water, and prevents its rapid and free passage. During such delays in its flow toward the stream channel, the vegetation incidentally takes up more or less of the moisture and evaporates it or uses it in plant growth. The torrential character of the stream will be somewhat modified, not materially perhaps, but an influence has been introduced in the direction of equalizing the flow.

On the other drainage area where the most uniform conditions of flow prevail, if vegetation be introduced on its drainage area, modifications in the conditions of flow will also take place. Instead of the rain sinking quickly into the soil, more or less of it will be taken up by the vegetation. If roots fill the soil to a considerable extent, a sod is produced and the water will not enter the soil as rapidly as it could if the sandy soils were uncovered. The trees, if the area is covered by a forest, receive the rainfall. There is then a great receiving area introduced, through which slight showers never penetrate to the ground, but are received on the foliage and are lost in evaporation, while the maximum rains, retarded in their passage into the soil, run more readily into the stream channel and increase the flood discharge. Any material changes introduced on either one of these two ideal drainage areas, change the original conditions which produce in the one case the maximum flood flow, and in the other case the minimum flood flow, and necessarily modify these conditions.

THE FACTORS OF RUN-OFF.

A great many factors enter into the problem of run-off, and their consideration is necessary in connection with the intelligent study of the flow of streams.

The discussion of these factors in any detail, in the limited time available, is impossible. Some of the principal factors may be briefly mentioned as follows:

1. *Precipitation.* This factor may be said to be of primary importance, as without precipitation there can be no run-off. The total amount, its distribution throughout the year and geographical extent of the maximum storms, and the intensity of occurrence are very variable and important factors for consideration.

2. *Temperature* will modify run-off at certain seasons of the year in certain localities. With low temperatures, precipitation will occur as snow and be so retained on the drainage area. The saturated ground may be frozen and made temporarily impervious, thus assuring rapid run-off if rainfall occurs while this condition obtains.

3. *Topography.* The abrupt topography essential to the quick run-off has already been briefly discussed. Low gradients and flat slopes produce slow surface flows and modify both seepage and evaporation.

4. *Geological* conditions are also important. Pervious material, sand, and sandstone have a very marked effect in inducing seepage and retarding run-off. I recently visited a drainage area in a western state where there is seldom or never any run-off unless there is a rainstorm of more than $\frac{1}{2}$ in. The area is located in the Dakota sandstone in a semi-arid region, and the ordinary rains sink into the ground and appear in the flow of wells, and the stream has no flow except the flood flows due to very heavy rains. The valley has an abrupt topography and at times of very heavy rains there are very high flood flows with a run-off of 50 cu. ft. or more per second per square mile.

5. *Surface Conditions.* Forest or desert, cultivated fields, grass lands, etc., may introduce important modifying conditions.

6. *Natural Storage* includes, among other conditions, the sand and sub-surface storage already mentioned, as well as lake and swamp surface storage, which both influences surface flow and modifies evaporation.

Other modifying influences include:

7. *Drainage Area*—size and shape.

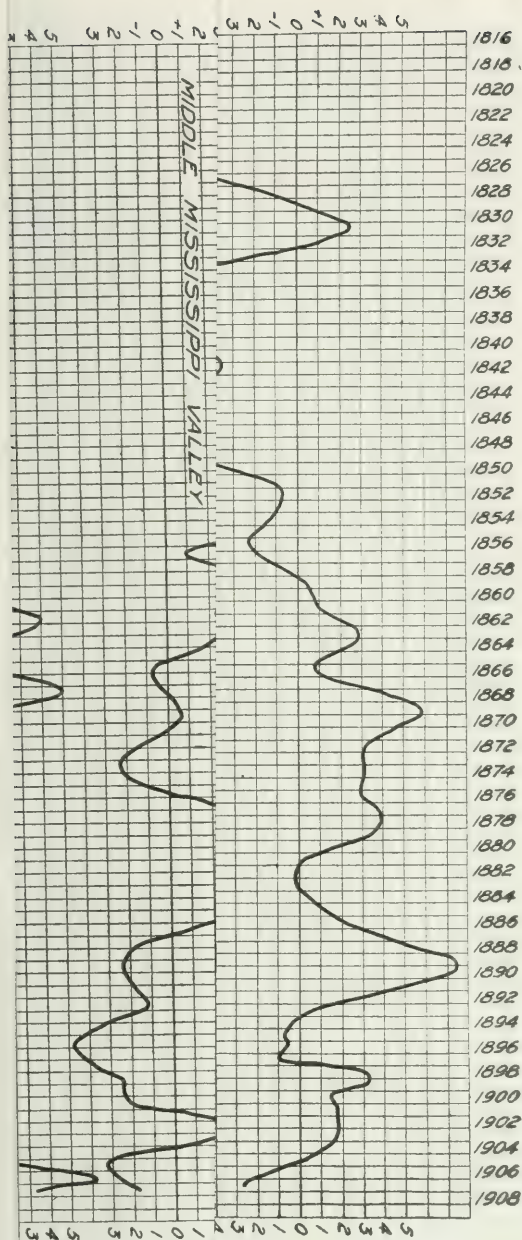
8. *Gradient and Tributary Arrangement of Streams.*

9. *Artificial Control, Construction of Reservoirs, Restrictions of Channels, etc.*

10. *Artificial Uses.* Where waters are used for irrigation, or diverted, perhaps, to other valleys for various purposes.

11. *Normal Winds*, somewhat insignificant, but frequently modifying the distribution and occurrence of rainfall.

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6. Diagram Showing
Various

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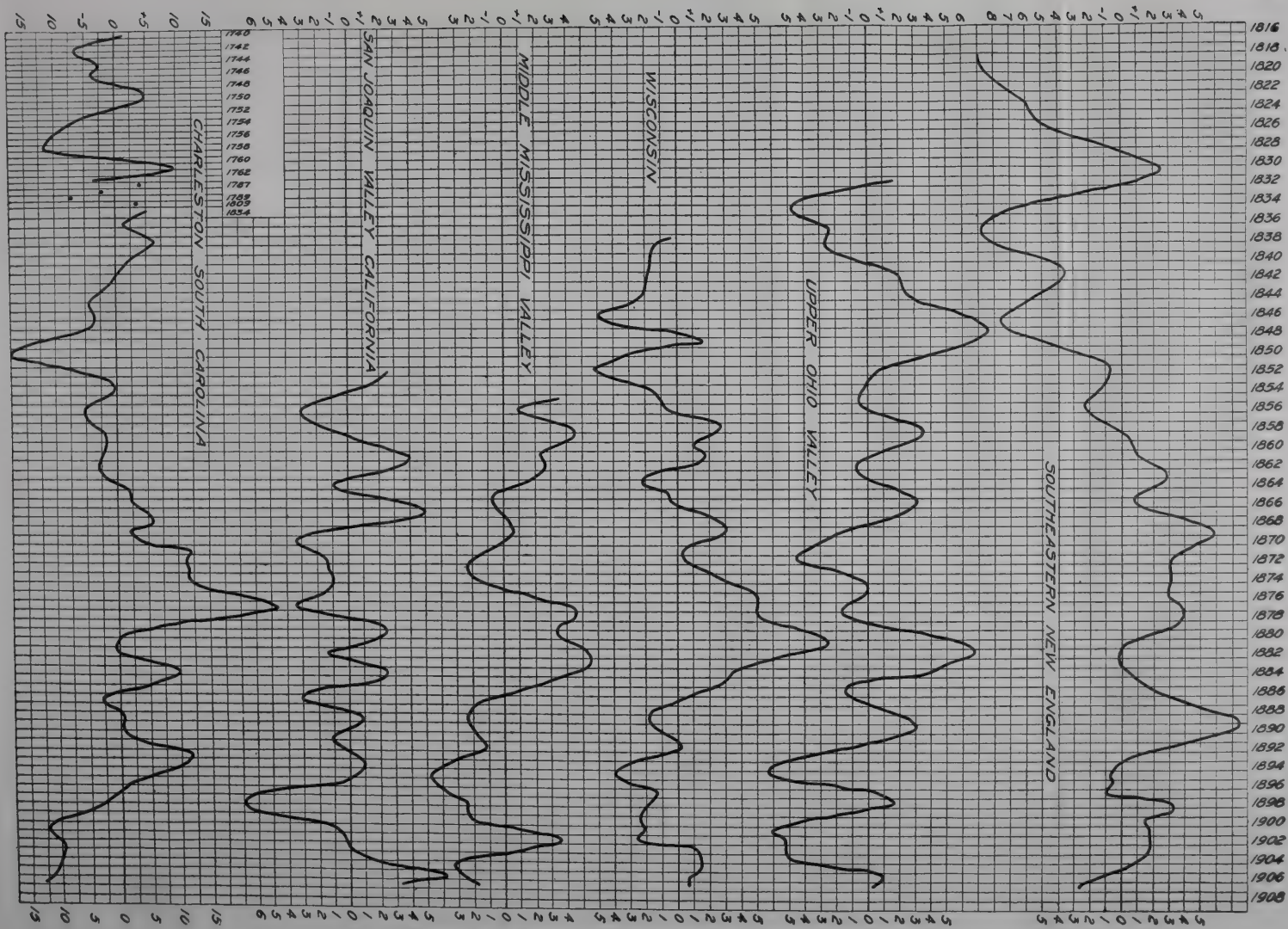


Fig. 16. Diagram Showing Progressive Mean Annual Precipitation at Various Localities in the United States.

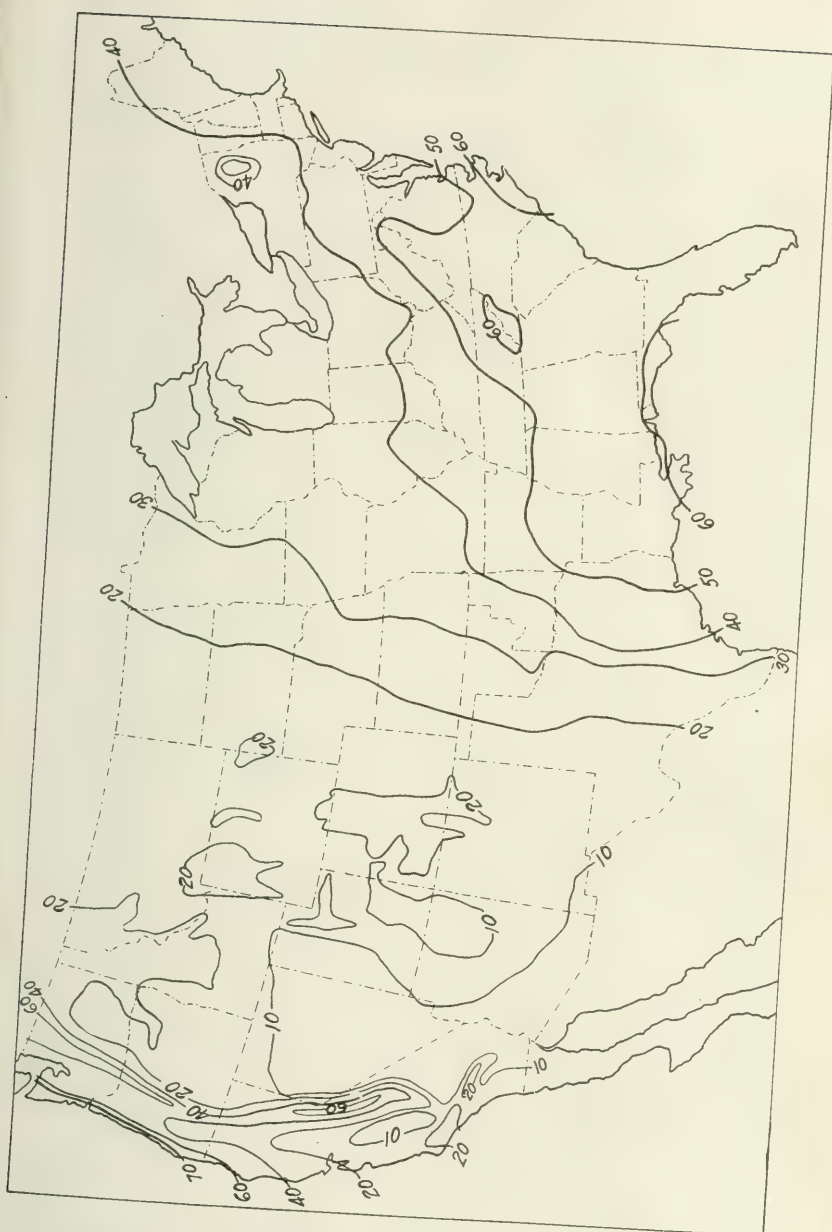


Fig. 15. Mean Annual Precipitation in the United States.

12. *Ice Formations.* This factor may become very important for the accumulation of snow and ice when affected by sudden rises in temperature, and may give rise to considerable floods. The formation of ice may also obstruct channels and produce serious overflow or power conditions.

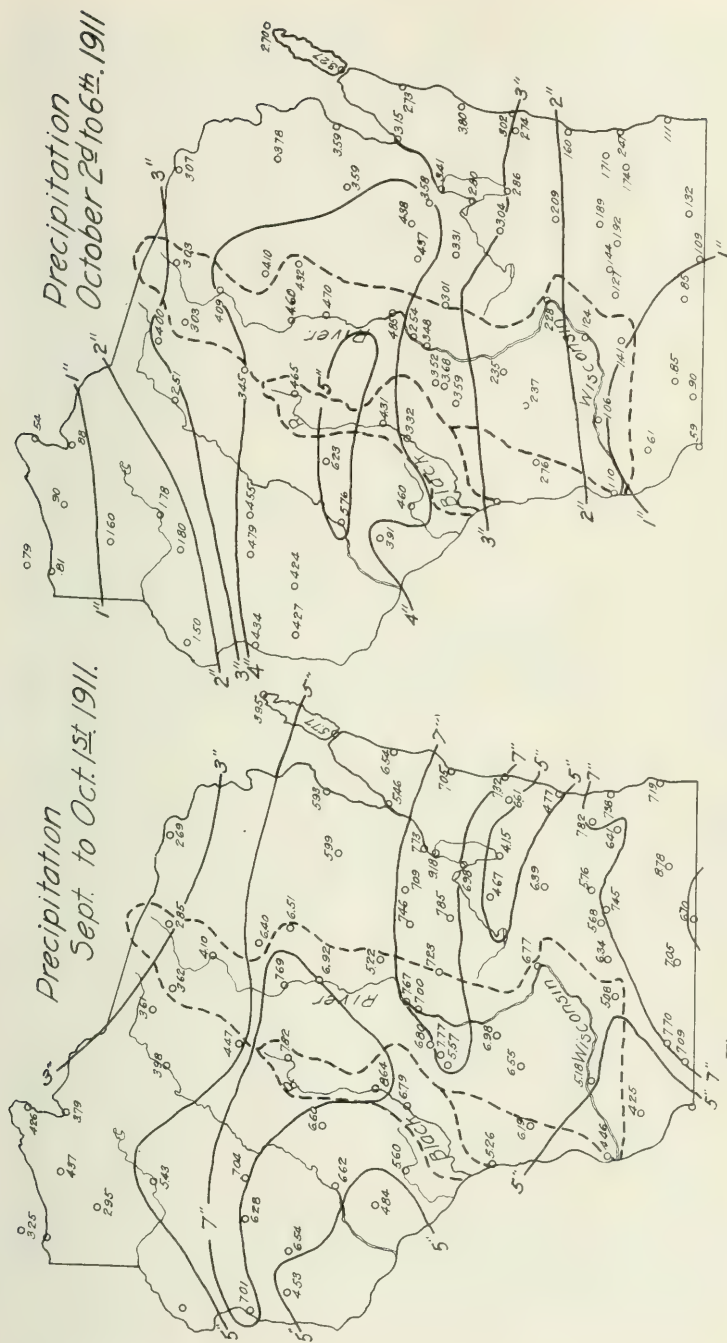
13. *Evaporation.* A factor which may, under conditions of surface storage, seriously modify total run-off.

14. *Change in Channels.* The clogging of channels may result in conditions favorable to unusual overflow.

An examination of a map showing the mean annual precipitation in the United States (Fig. 15), will indicate at once how absurd it is to try to devise a general run-off formula. This map will show a mean annual precipitation along the Atlantic coast as high as 60 or 70 in., while in Southern California and New Mexico the annual rainfall is as low as 2 in. or less. Through Colorado the mean precipitation is 10 or 15 in., and along the north Pacific coast, as high as 100 in. or more. The streams above discussed are in Wisconsin and Michigan where the precipitation is from 30 to 40 in. per annum. Here the conditions of rainfall may be said to be reasonably uniform, and if a formula that will fairly represent flood flow cannot be devised for such a district, how can we hope to devise a formula which will include the rivers of the United States under the great extremes of rainfall that exist?

Figure 16 is a chart that shows the annual rainfall conditions for a considerable period, for various sections of the country. The curves shown are the progressive means of the annual rainfall and do not represent extreme conditions. On the diagram is shown progressive means of rainfall in New England, beginning about 1818, and it shows the very great variations that have occurred during a long series of years. From 1830 to 1850, the rainfall was below the mean; following this period for a long series of years the rainfall was above the mean. Similar curves of rainfall are also shown for other localities. This diagram shows the great changes and variations that occur in the annual rainfall of any locality, and illustrates the difficulty in correlating the influences of factors which vary so greatly, and yet which are so important in these hydraulic problems.

In connection with this subject, however, I wish to call your attention to the rainfall conditions that preceded the flood of October, 1911, in Wisconsin. The flood was somewhat local in character. The rainfall that actually caused the flood was preceded during the thirty days, from September 3rd to October 1st, 1911, by precipitation, the amount and distribution of which is shown in Fig. 17. From October 2nd to October 7th a rainstorm occurred of over 6 in., through the Wisconsin and Black River valleys. The distribution of this storm is shown in Fig. 18. The heaviest rainfall in this storm, it will be noted, extended across the upper portion of the Black River valley, and as a broad band across a portion



Figs. 17 and 18. Distribution of Rainfall, Causing Floods in Wisconsin, October, 1911.

of the Wisconsin River valley as shown on the map. The heavy portion of this storm, it will be noted, was south of the headwaters of the Wisconsin River where a reservoir system has been constructed. These reservoirs were constructed for equalizing the flow of the stream for water-power purposes. This condition is perhaps worth considering from the viewpoint of the desirability of constructing reservoirs on the upper part of a river valley for the prevention of floods. The rainfall must fall upon the area above the reservoirs before they can effect run-off, and many of the heavy rainfalls producing floods on the Wisconsin River have occurred south of the reservoir system. Another point which is important and worthy of attention is that, if the axis of the heavy rainstorm belt follows the line of the stream, such coincidence may seriously increase the floods of such a stream. The study of the individual rainstorms that occur upon a drainage area is therefore exceedingly important.

While rainfall is a most important factor in run-off, it does not necessarily follow that the greatest rainfall gives the greatest run-off. Figure 19 shows three curves of distribution of relative rainfalls and stream flow on three Wisconsin streams. In the curve showing the conditions on the Wisconsin River above Portage, it should be noted that the month of highest water is April, while the month of the highest average rainfall is June. The condition of highest water obtains before the time of the highest rainfall, and the lowest water occurs in the months that are among the highest rainfall months. The reason of this is that other conditions besides rainfall are equally important in their effects on flood flows. The floods of April are, of course, very largely floods that are due to the storage of snow and ice during the winter months and not particularly to heavy spring rains. In June and July, under normal conditions, the flow of the stream begins to decrease, although the rainfall may have increased considerably, because the ground water has become somewhat exhausted in keeping up the flow of the river through the winter, during which season stream flow has been due very largely to the ground storage. When the ground has become thoroughly saturated in the early spring, May and June floods sometimes occur with the heavy rains of those months. When vegetation begins to develop, and during the entire growing season, heavy rainstorms have very little effect on the flow of streams, for much of the rain is absorbed by vegetation or is lost in evaporation. In October vegetation begins to die and heavy rainstorms will again begin to affect the flow, and occasionally result in high fall floods.

Figures 21 and 22 show a study of the run-off of three creeks in the vicinity of Philadelphia, which have been considered as possible sources of water supply for that city. In this diagram the ordinates show the rainfall in inches, and the abscissas, the inches of run-off. It will be here noted that the run-off is sometimes very

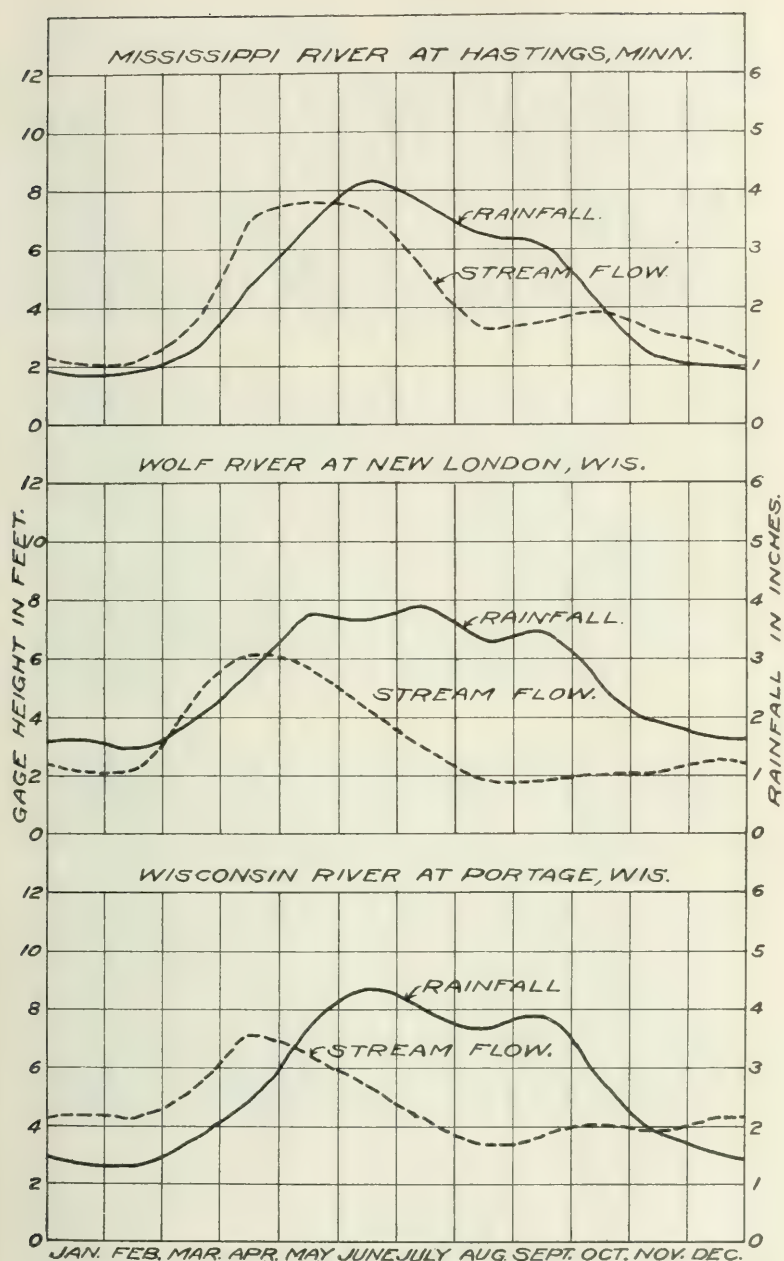


Fig. 19. Diagram Showing Relation of Average Monthly Rainfall and Average Stream Flow of Some Wisconsin Rivers.

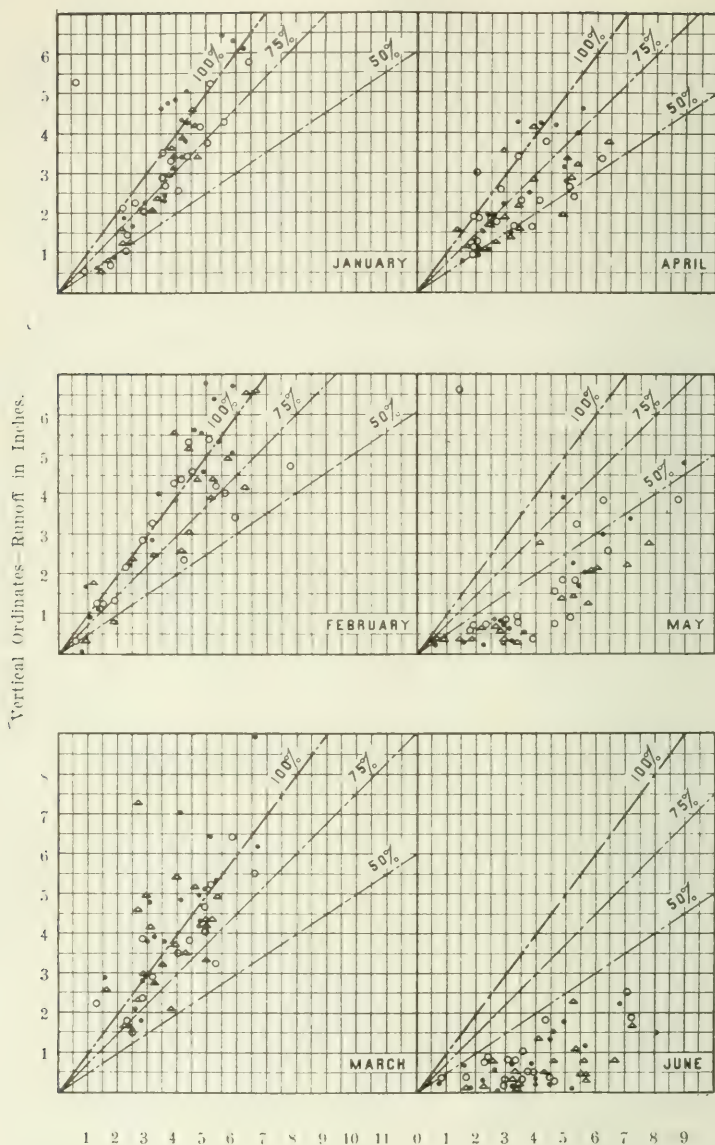


Fig. 20—Rainfall and Runoff, Tohickson, Neshaminy and Perkiomen Creeks, Near Philadelphia, Pa.

Horizontal Ordinates—Rainfall in Inches.

Tohickson Creek Watershed—Area 102.2 Sq. Miles.

△ Neshaminy " " " " 139.3 " "

○ Perkiomen " " " " 152.9 " "

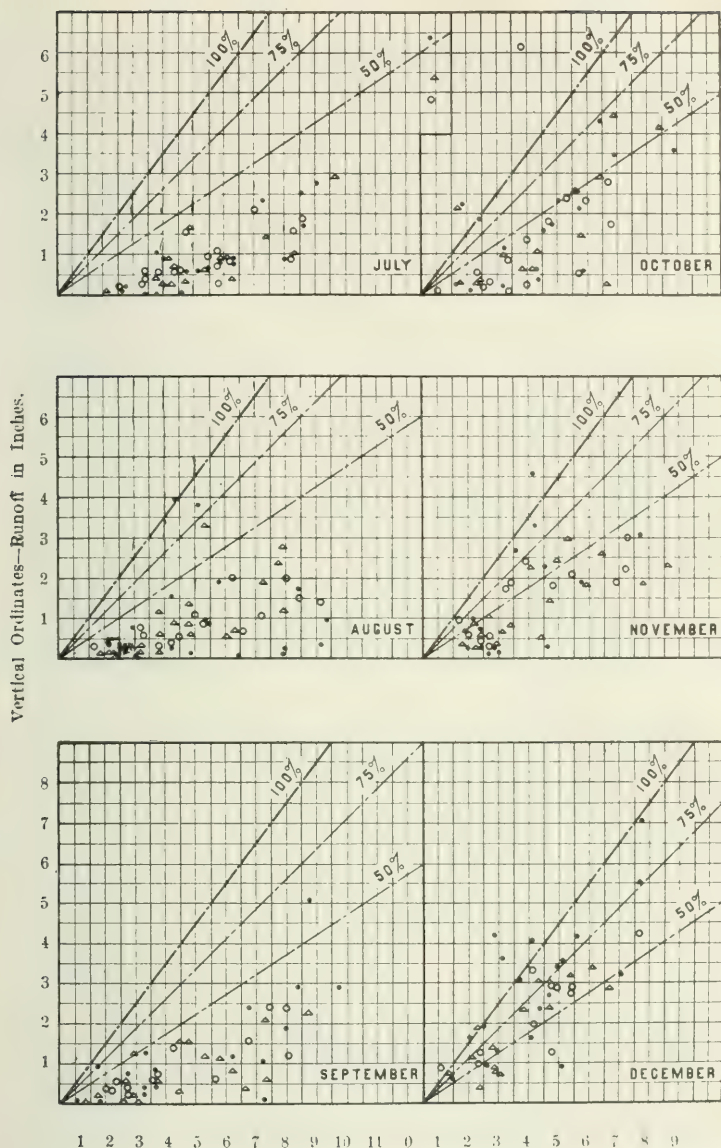


Fig. 23.—Rainfall and Runoff. Tohickson, Neshaminy and Perkiomen Creeks, Near Philadelphia, Pa.

Horizontal Ordinates—Rainfall in Inches.

•	Tohickson Creek Watershed	Area 102.2 Sq. Miles.
△	Neshaminy	139.3
○	Perkiomen	152.0

high in the early months,—sometimes 100% or more. This is due to the fact that the run-off is due not only to the precipitation of the month, but also to the preceding months as well. As the season advances the percentage of run-off begins to drop. In April the percentage of run-off has decreased to about 50% of the rainfall. In May, the percentage is below the 50% line, and in June the run-off is about 25% of the rainfall. In July and August the percentage of run-off still remains small, but in September there is a tendency for the ratio to increase, and some of the data show discharges of 50%. In October the percentages are still higher, and in November and December they rise still more. There is evidently some law which is here affecting the results,—a very distinct law no doubt, and one that perhaps can be formulated. A study of such facts may not lead to an exact basis for estimate, but they do give us something of the changes that are occurring on a particular stream under particular conditions, and for that reason I think they are of considerable value.

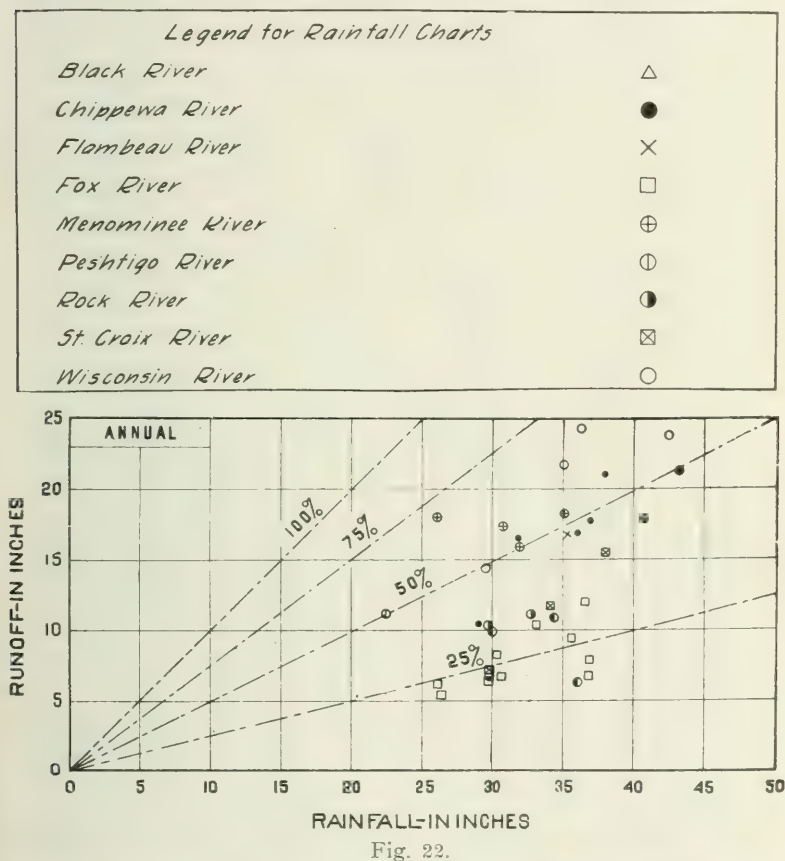
The study of the relation of the annual rainfall and run-off is interesting, but of questionable value for anything in the way of exact estimates. In Fig. 22 are shown the relations of a number of rivers in Wisconsin. In the higher group are found the Menominee, the Chippewa, the Wisconsin, and the Black rivers. The annual run-off on these streams will average about 56% of the annual rainfall. This rate varies considerably from year to year, dropping in some cases down to perhaps 37% and rising almost to the 70% line. The Rock River, the Fox River, and the St. Croix River, in all but exceptional cases, are rivers of comparatively low flow and their annual flow will average about 26% of the annual rainfall. In these rivers, all in Wisconsin, the conditions of rainfall are essentially the same, and yet, the average flow of one group of rivers is less than one-half of the flow of the rivers of the other group. I think this diagram illustrates and emphasizes the danger that will result from any attempt to derive a general formula for either the average of extreme run-off of streams, or for any individual stream without individual investigation and study. To understand and appreciate these conditions, extended study and investigation is necessary.

Experience without study is dangerous. It can be readily seen that if, without study and investigation, an engineer from the Fox or Rock river valleys should attempt to design the spillway of a dam on the Wisconsin River and should base his design solely on his experience, he would be very apt indeed to design the spillway too small. On the other hand, if an engineer with experience on the Wisconsin or the Black rivers should attempt to design such structure for the Fox or the Rock rivers without a study of the local conditions, his design would probably be uneconomical and expensive.

These matters are not matters of simple individual experience. For their intelligent consideration they involve consideration of

principles and conditions, extensive investigations and extended measurements; and without such investigation and such consideration, these disasters will continue to occur until the waste will finally lead to the necessary precautions, both legislative and professional.

A graphical method of studying the relations of rainfall to run-off as applied to the Wisconsin River, is shown in Figs. 23 and 24. I think this method of study is worthy of some little attention. The diagram was first used by Landa, an Austrian engineer,



in a paper before the International Navigation Congresses. Each diagram shows cumulative curves of rainfall, run-off, and retention. The upper curve in each case is the curve of rainfall and represents the cumulative amounts of the total rainfall from day to day, from the first of the year. Where the line is horizontal it shows there was no rainfall for the corresponding time. The difference in height of ordinates shows the amount of rainfall for the corresponding period. The run-off is shown the same way. The steeper lines

April, 1913

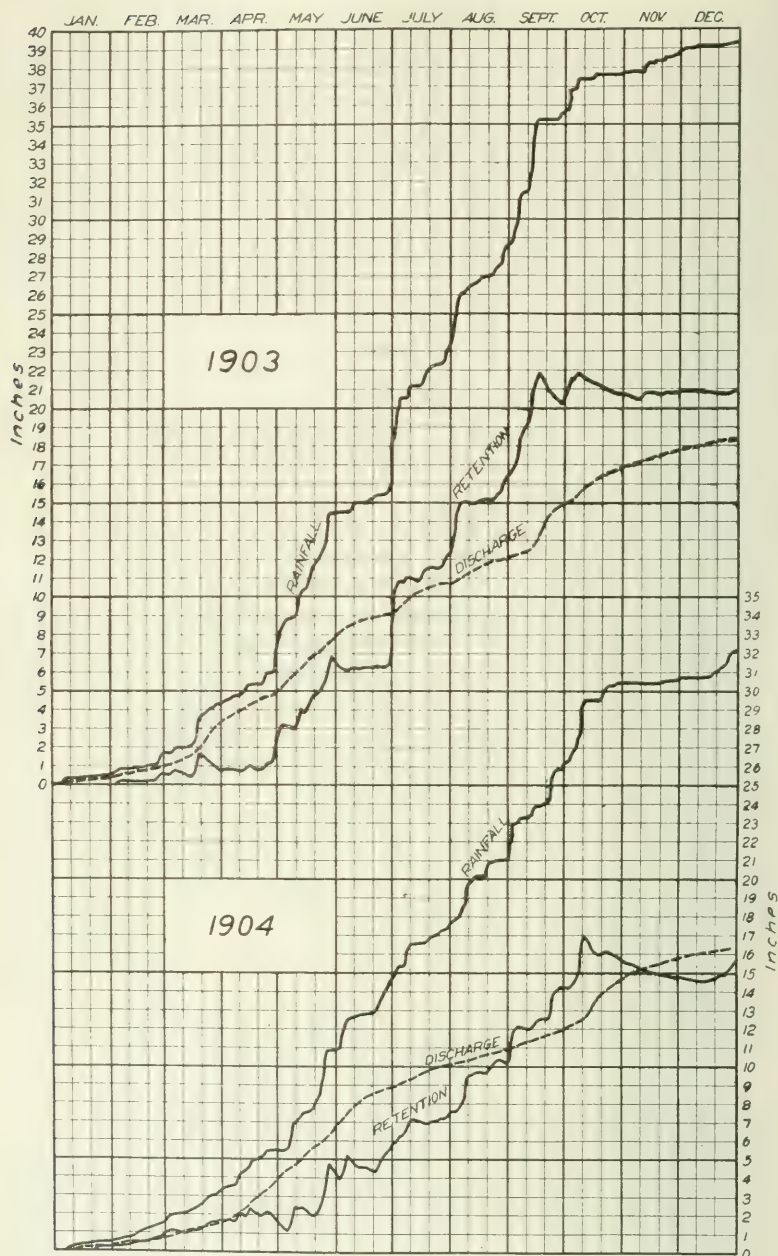


Fig. 23. Cumulative Curves of Rainfall, Runoff and Retention on the Wisconsin River Above Necedah, Wis.

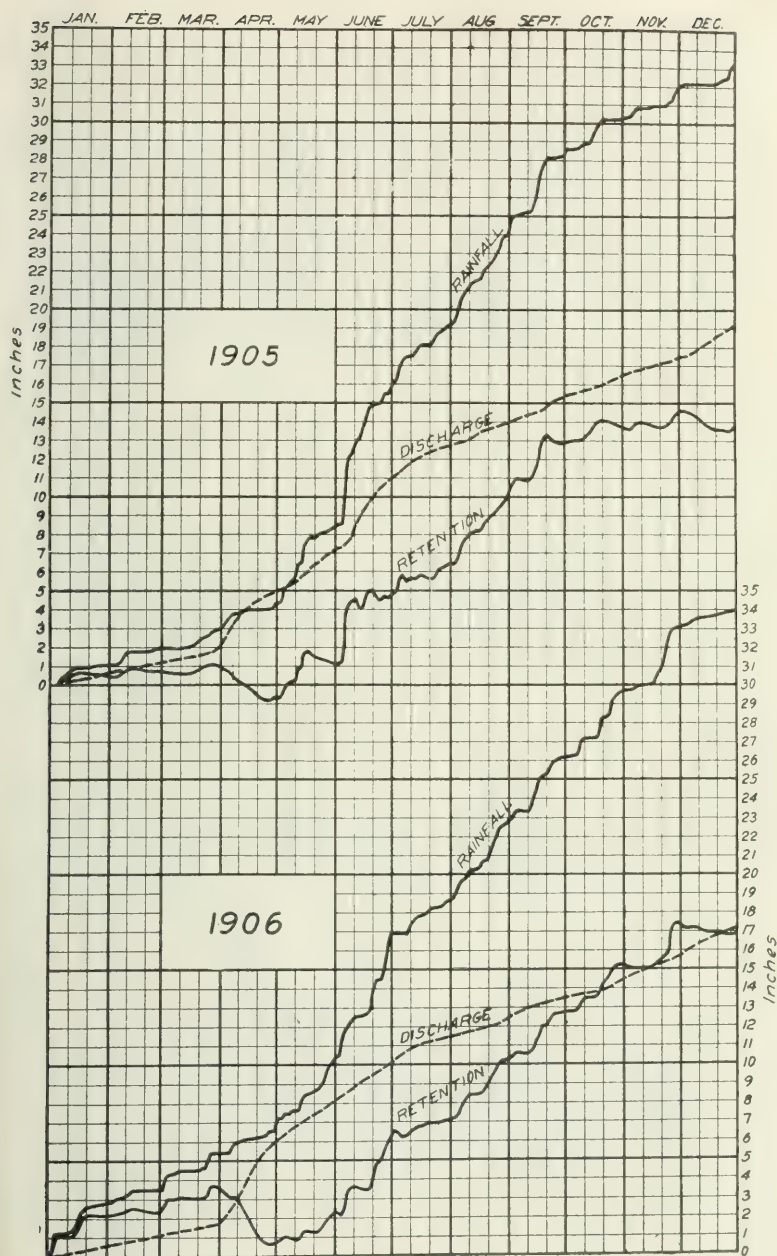


Fig. 24. Cumulative Curves of Rainfall. Run-off and Retention on the Wisconsin River Above Necedah, Wis.

of run-off in the fore part of the diagram show the high spring flow, not quite as well, perhaps, as with the hydrographs before used, but nevertheless very distinctly. The decrease in the gradient in the summer months shows that the flow was considerably less. I have used the term "retention curve" for the third curve, because I could think of no better title. In our investigation we have the rainfall, the run-off, and the retention; that is, that part of the rainfall that did not flow off. This part of the rainfall was taken up in seepage, by plant life and in various ways. Figure 24 (1905) shows that, up to the latter part of April, more water had run off than had fallen in rain, which means, of course, that some of the December snow was carried over and went off with the spring floods. The retention curve is negative. In other words, the flow had been augmented from the snows, the ground water, or some other source, besides the year's rainfall to the amount of 1 in. When there is a high gradient to the retention curve, it means that a large percentage of the water is not running off; as for example, after the growing season has opened. About the last of September, when there is not much active vegetable life on the drainage area, there is a comparatively small amount of water lost in evaporation or taken up in plant life, and the retention curve, therefore, has a low gradient.

The retention curve for October to December, 1904 (Fig. 23), shows the fact that sometimes rainwaters taken into the ground water come back to augment the stream flow, and a descending retention curve results. This shows, in the best way I have ever been able to devise, the fact that the rainwaters are sometimes stored and given back by the lakes, marshes, sands, and gravels on the drainage area.

The rainfall and run-off of the Wisconsin River above Necedah (Figs. 25 and 26), are shown in a different manner. The points to be noted in these diagrams are, the amount and distribution of the rainfall, and how differently it affects the streams at different times. In the spring of the year, a comparatively small amount of precipitation results in a considerable flood if the temperature is sufficiently high. With low temperature, precipitation may fall in the form of snow, and there may be considerable precipitation but no flood. The heavy rains of summer should be noted (note years 1908, 1909 and 1910), and how little they affect the flow of the stream. The stream is scarcely raised at all compared with the early floods resulting from even a less precipitation.

In presenting these data it is my intention to show some of the methods used in the study of this subject. Many of these methods are by no means new, but collected together in this discussion they may be of some interest to those who desire to study this important subject.

Three hydrographs which further illustrate the matter under discussion are shown in Fig. 27. Here are three streams in the State of New York,—the Hudson River, which corresponds closely

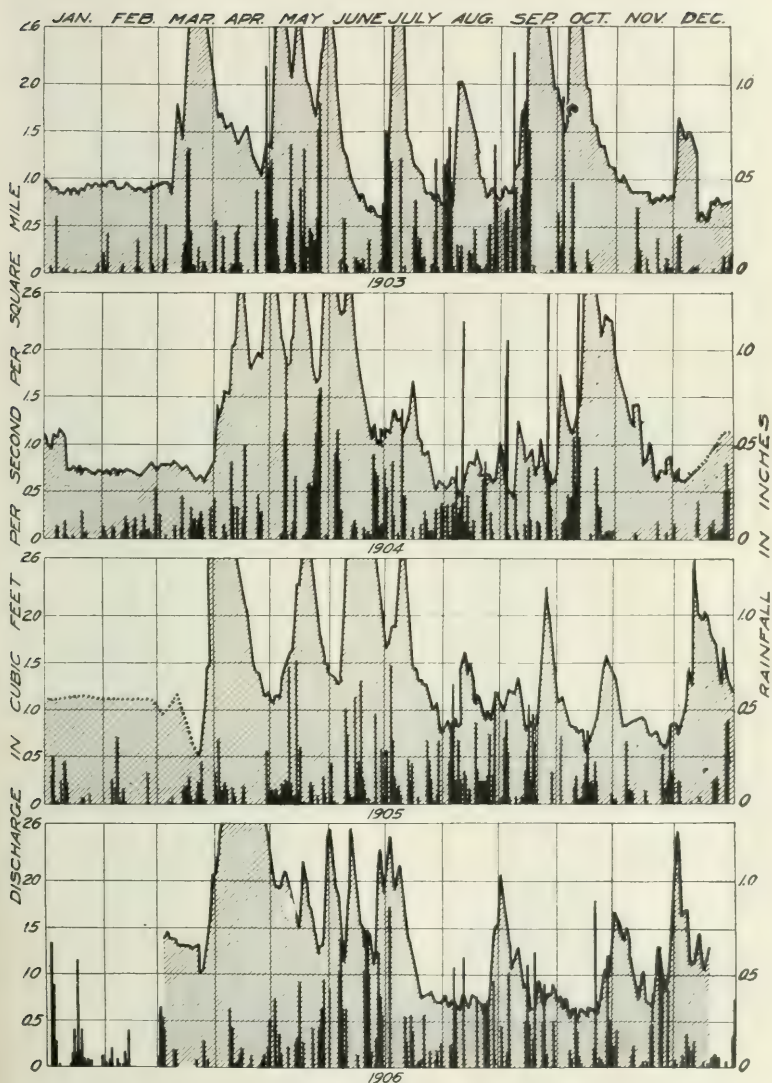


Fig. 25. Hydrographs Showing Daily Precipitation and Run-off of the Wisconsin River Above Necedah, Wis., 1903-1906.

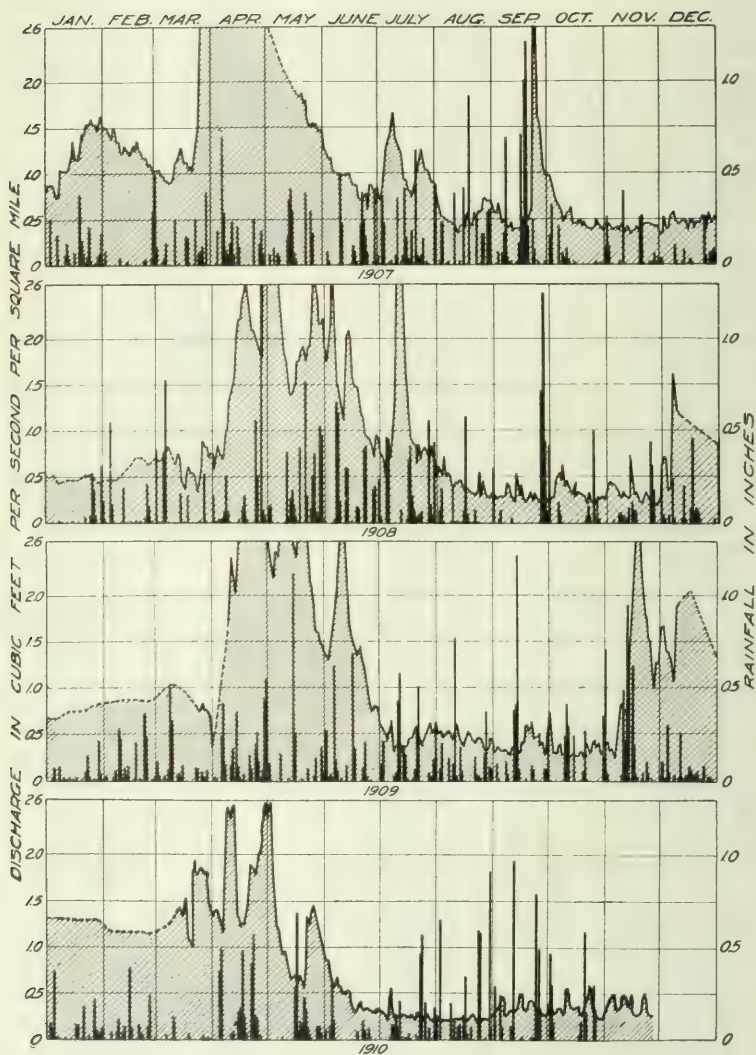


Fig. 26. Hydrographs Showing Daily Precipitation and Run-off of the Wisconsin River Above Necedah, Wis., 1907-1910.

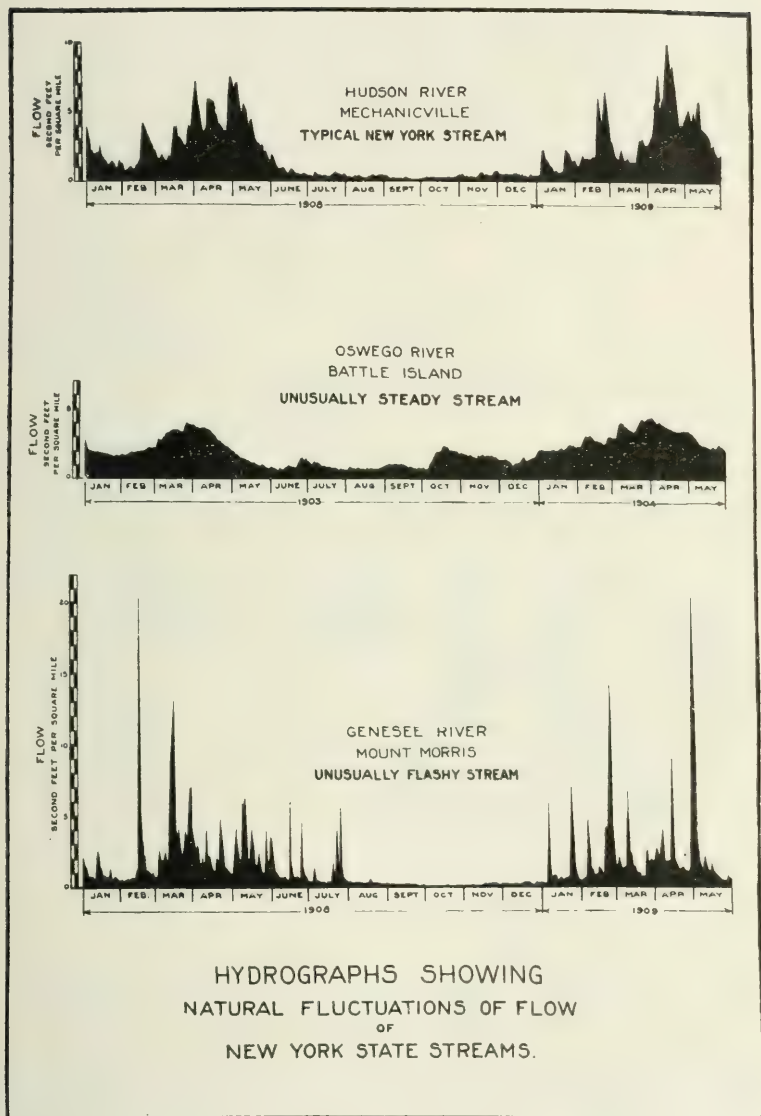


Fig 27.

with many Wisconsin streams; the Oswego River, which has a large lake storage on its drainage area, and is in consequence a stream of low flood flow; and the Genesee River, which is an unusually flashy stream and has floods as high as 21 or 22 cu. ft. per second per square mile, and a low water run-off of not more than 0.2 cu. ft. per second per square mile. Here again we find in the same state, and under conditions of rainfall not greatly different, great extremes in the flow of rivers. On the Oswego River (Fig. 28), there are numerous large lakes which are the cause of the



Fig. 28. Drainage Area of the Oswego River, New York, and Natural Storage of the Same.

regularity in flow. It should be noted, however, that with all this lake storage, the Oswego River does not compare in its regularity with the flow of the Manistee River, which is regulated largely by the sand deposits of northern Michigan. Figure 29 shows the Genesee River drainage area, practically without storage; a long, narrow basin with steep slopes from which the water rushes off in what we might almost call torrential flow, at least torrential as compared with the other streams.

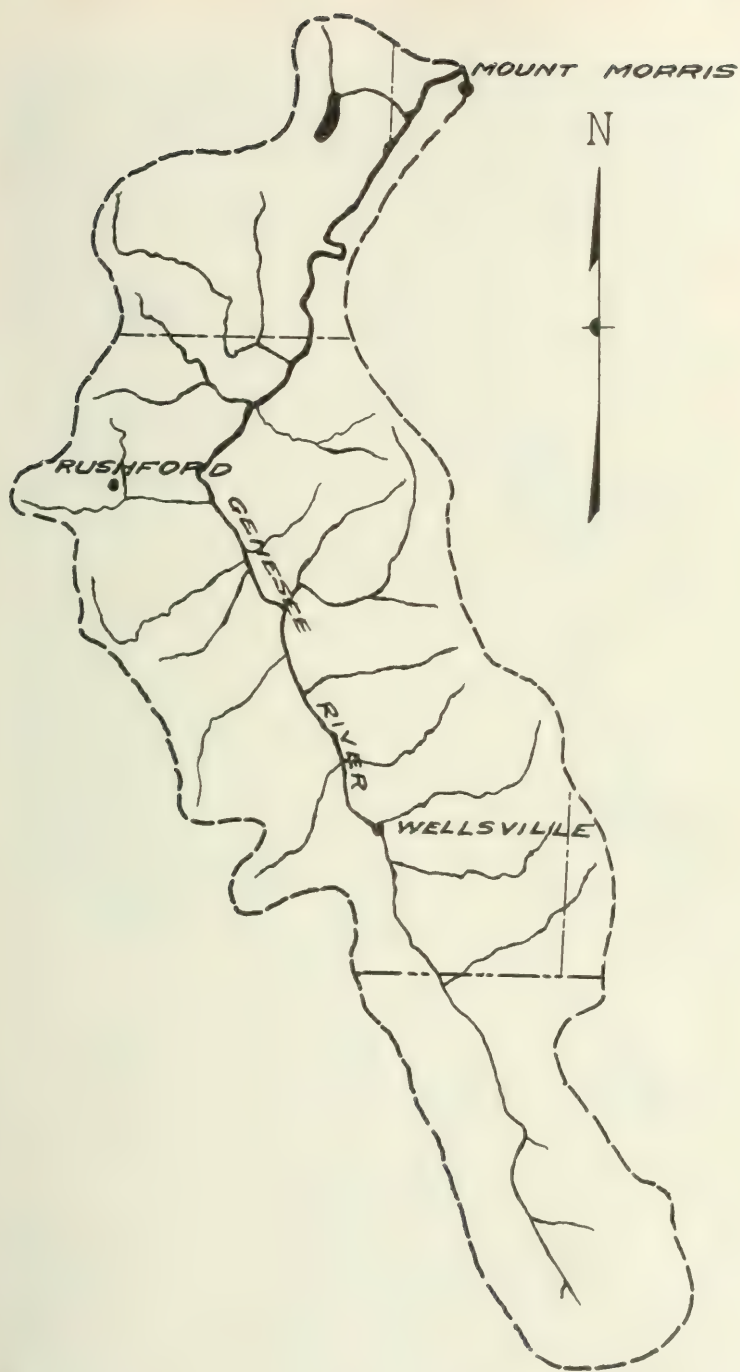


Fig. 29. Map of Drainage Area of the Genesee River, New York.

Attention is again called to the hydrographs of the Wisconsin and Rock rivers as shown in Fig. 14. These hydrographs show the great difference in high and low water between these two rivers. As a general average, the flow of the Rock River is about one-half that of the Wisconsin River per unit of area, with essentially the same rainfall. Why this difference in flow is so great, I am unable

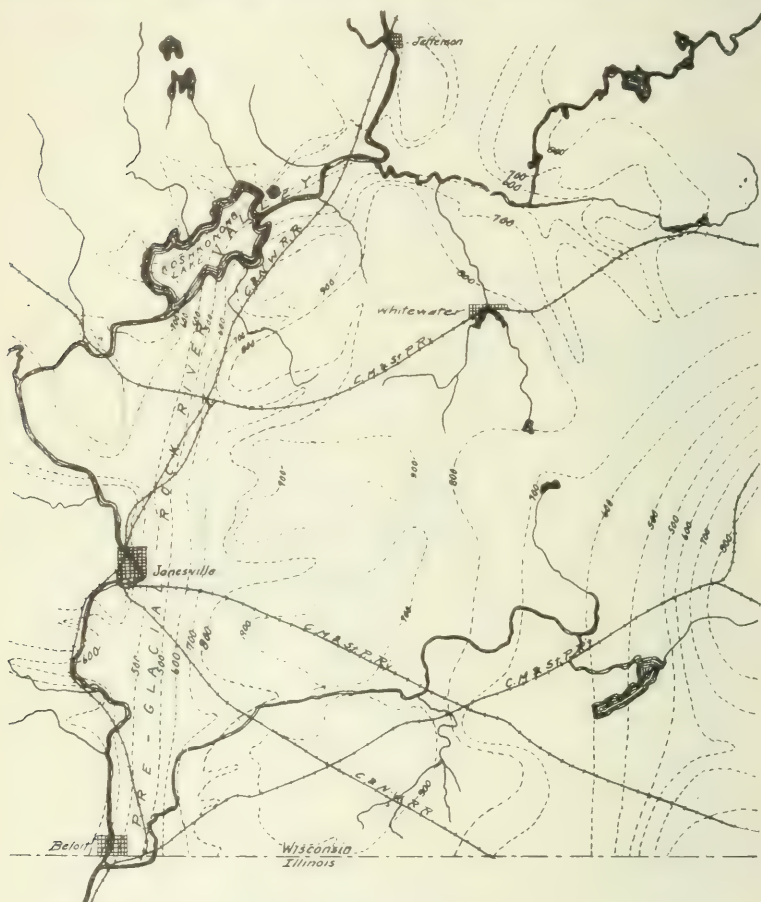


Fig. 30. Map Showing Pre-Glacial Valley of the Rock River in Southeastern Wisconsin.

to say. One of the reasons for the difference is the fact that the Rock River (a map of which is shown in Fig. 30), from Lake Koshkonong through Janesville, to and below Beloit, shows that the river is flowing over its pre-glacial valley which lies 300 ft. or more below the present valley. The old valley which has been filled with sand, gravel, and glacial deposits of various kinds, car-

ries a very large amount of water which diminishes, to an extent, the surface flow of the present river. I do not think that the entire difference in flow between the Rock and the Wisconsin rivers passes off in this subterranean stream, but I do believe that this is one of the important factors. Cultivation is another factor. This valley is cultivated to a greater extent than the Wisconsin valley, and I think through the cultivation of the land,—plowing and seeding,—a great deal of water is taken up, evaporated, and lost, and hence never reaches the streams. Another unfavorable influence to total annual run-off is the number of swamps in the valley, and while swamps act as a storage and reduce floods, they do not add to the low water flow of a stream, as a rule, because generally they are shallow and the evaporation from them is therefore high, and the total run-off is therefore reduced.

I will call attention briefly to the question of the influence of forests on stream flow. It is an important matter to know whether forests do or do not have a marked effect on flood intensity and on total run-off. In discussing the question I wish to say that I do believe earnestly in forestry; not on account of its effect on the flow of streams, because as far as Wisconsin is concerned I do not believe forests have any marked effect on stream flow, but I do believe that we owe it to future generations to reforest the waste lands of the country and secure to future generations the advantages of forests which have been so useful to us. We never can replace the great forests which have been destroyed, for many of the lands deforested are of greater use for other purposes; but there is a very large amount of waste land throughout the country which can be utilized for forest planting, and I am heartily in sympathy with the movement for the reforestation of these areas.

Wisconsin was one of the great forest states. The cutting of timber began a good many years ago; the records of cutting from 1873 to 1908 are shown approximately in the following table:

Million Feet		Million Feet	
B. M.		B. M.	
1873	1240	1888	3210
1874	1200	1889	3270
1875	1250	1890	3660
1876	1340	1891	3010
1877	1000	1892	4010
1878	980	1893	3490
1879	1470	1894	3100
1880	1920	1895	2800
1881	2190	1896	2080
1882	2580	1897	2430
1883	2750	1900	3389
1884	2950	1905	2543
1885	2710	1906	2331
1886	2680	1907	2003
1887	2890	1908	1613

April, 1913

You will note from the table that the maximum cutting gradually increased to about 1892, and has gradually decreased since that date. If forests have an important effect on the flow of streams it would seem that such effect would show on the record of the

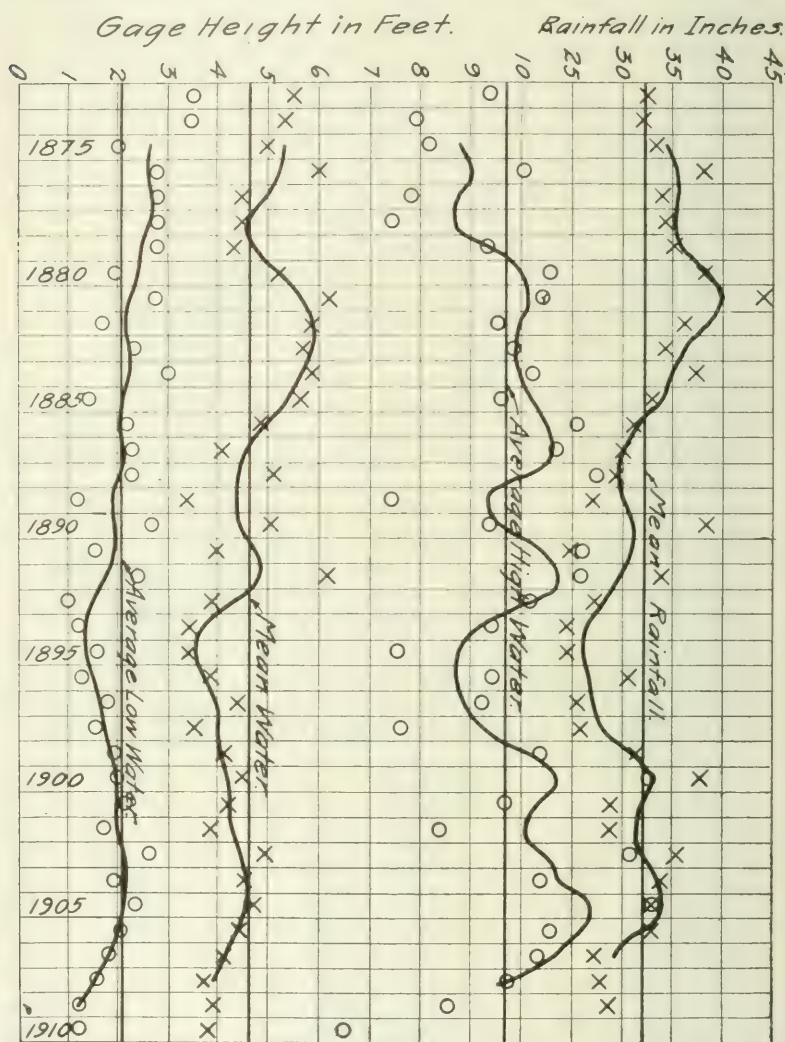


Fig. 31. Comparison of Mean Annual Rainfall With Mean and Extreme Gauge Heights of Wisconsin River at Portage, Wis.

stream itself during this long period, and if such effect cannot be found from a study of the flow during this period, it must be so insignificant as to be of no particular importance.

In Bulletin 425 of the University of Wisconsin on "The Flow of Streams and the Factors That Modify It," the writer has prepared a diagram (Fig. 31), which shows:

1. The annual precipitation for each year, the mean for the period, and the progressive means during the same period.
2. The annual maximum gage height, the mean of the maximum annual gage height for the period, and the corresponding progressive means of maximum gage heights.
3. The mean annual gage height, the mean of the mean annual gage heights for the period, and their progressive means.
4. The minimum annual gage height, the mean of the annual gage heights, and their progressive means.

From this diagram it will be noted that the progressive means of the mean annual gage height and of the extreme low water, which conditions of flow are the result of continuous conditions during the year, follow closely the trend of the progressive average of the total annual rainfall. The extreme high water conditions of the country, being due to immediate conditions favorable to such results, are very irregular and do not follow so closely the variation in annual rainfall conditions. It is also evident that the relations during the earlier period are not markedly different from the later period.

Figure 32 is a chronological charting of the departure of the
 Rainfall
 ratio of ————— for each year. In this diagram the
 Gage Height

lower ratios show the better flow conditions. For example, the ratio of 30 in. of rainfall to 5 ft. or 6 ft. gage height would be 6 and 5 respectively. The ratio 5 here represents the mean annual gage height of 6 ft., which consequently represents a higher flow than gage height 5 and ratio 6.

The departure from the mean of these ratios is plotted for the period 1873-1910 on this diagram, and the progressive mean during the period is shown by the irregular heavy line. The position of this line above or below the mean line for the period shows a corresponding better or poorer condition of flow. If the forests or other early and normal conditions were favorable to increase stream

Rainfall
 flow, then the ————— ratio should be smaller in the earlier
 Gage Height

years and the line of the progressive mean should lie below the "mean line for the period." If deforestation has decreased this ratio, then the progressive mean of the ratio should lie above the "mean for the period" during the later years. If the forests and other early normal conditions served to regulate stream flow, and in consequence of the change, the regulation has been injuriously affected, then the progressive mean should agree more closely with

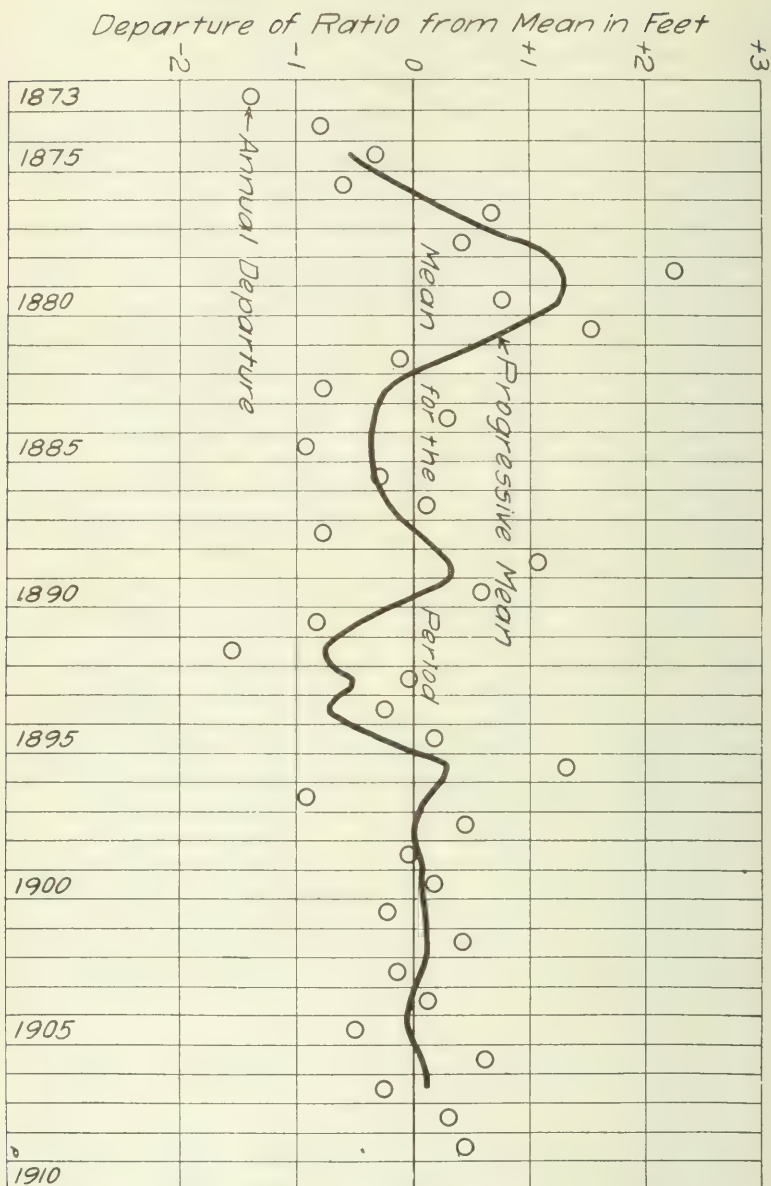


Fig. 32. Comparison of Ratios of Annual Precipitations to Mean Annual Gauge Heights on the Wisconsin River at Portage, Wis.

the "mean for the period" during the earlier, than during the later years.

The diagram shows clearly that the greatest extreme in these ratios took place in the first half of the period, the poorest ratio being in 1874 and the best in 1892. There are no indications that the ratios as a whole were uniformly better during the earlier years. The uniformity of flow during the last 15 years is much greater than at any time during the 22 years preceding. These and other studies have led me to believe that in Wisconsin deforestation has either had no serious effect on either flood or total run-off, or that such effect has been offset by other influences.

Your attention is called to the Wisconsin River at Rhinelander, at Merrill, at Necedah, and at Kilbourn (Figs. 33 and 34). It will be noted that there is a difference in the flow in cubic feet per second per square mile at these different points. These hydrographs are all comparative. You will note that the unit flow of the river per square mile of area is decreasing as we descend the river. The floods are all decreasing in the same manner. The floods are higher at Merrill, due to concentration of drainage area, and larger floods are possible on the smaller areas because maximum rainfall conditions do not extend over the larger areas. This variation is also due to a considerable extent to a difference in the physical character of the various portions of the Wisconsin drainage area.

Hydrographs of four rivers at points almost directly east and west across the state, are shown in Figs. 35 and 36. On these diagrams hydrographs are shown of the Menominee River between Michigan and Wisconsin; of the Peshtigo River, a few miles west; of the Wisconsin River, still further west, and of the Chippewa River. These hydrographs are shown to illustrate the similarity of flow of different rivers under fairly similar conditions. The comparison of one stream with another is very interesting and very important, but, as I have also tried to indicate, such comparisons are extremely dangerous unless the conditions are comparatively similar.

A study of the advance of a flood wave is of interest. In Fig. 37 are shown hydrographs at different points along the Wisconsin River during the flood of October, 1911. Above Rhinelander, where most of the reservoirs on the river are constructed, you will see there was practically no flood. There was a rise in gage height due to the lighter rainfall. The dam just below Wausau, shown in Fig. 2, went out and undoubtedly was one of the causes of the extra rise at Knowlton. At Grand Rapids the flood peak followed a little later. They blew out some of the gates at that point in order to help conditions, which, however, did not better them down the river.

It has been my purpose in this very general discussion to point out some of the factors of flood flow, and some of the difficulties of the study of the maximum intensity of run-off on any stream.

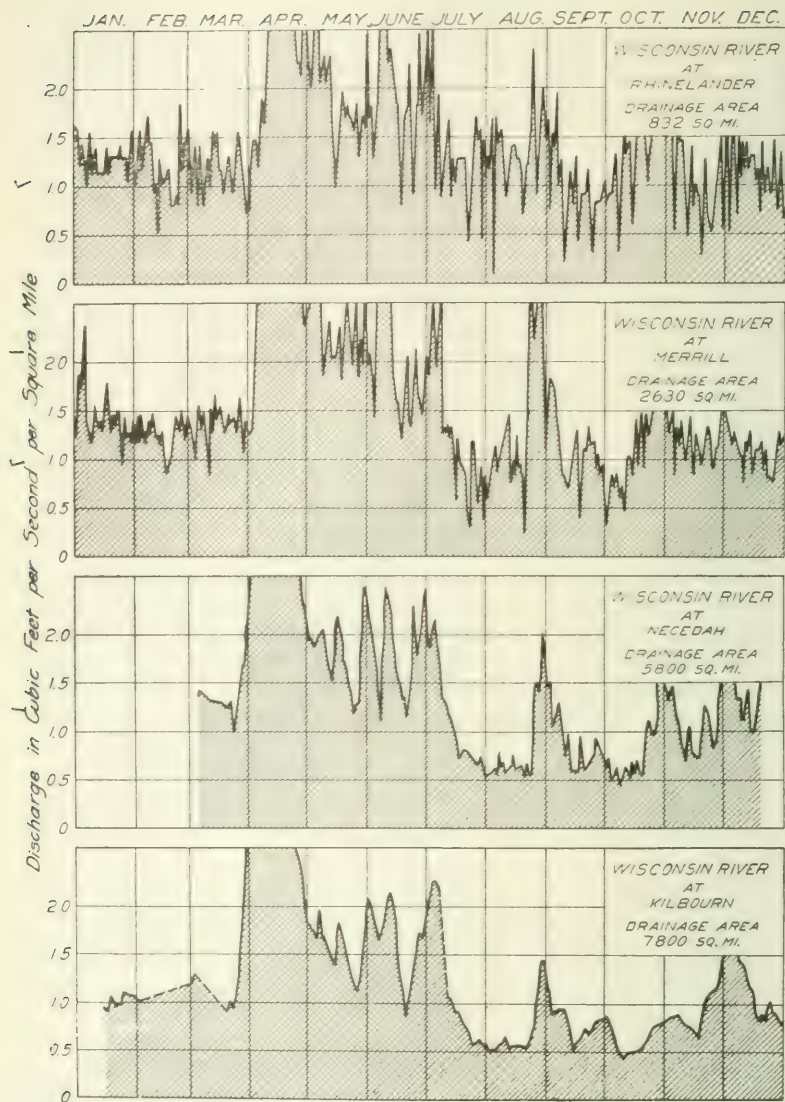


Fig. 33. Comparative Hydrographs of the Flow of the Wisconsin River, 1906.

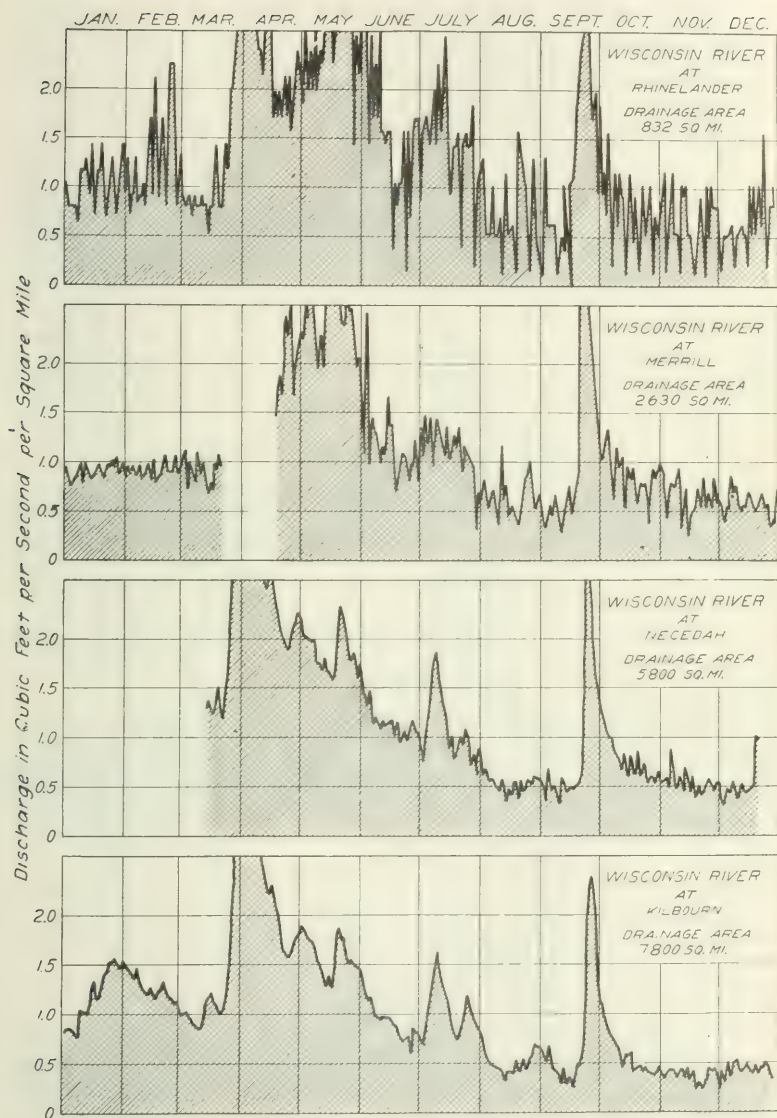


Fig. 34. Comparative Hydrographs of the Flow of the Wisconsin River, 1907.

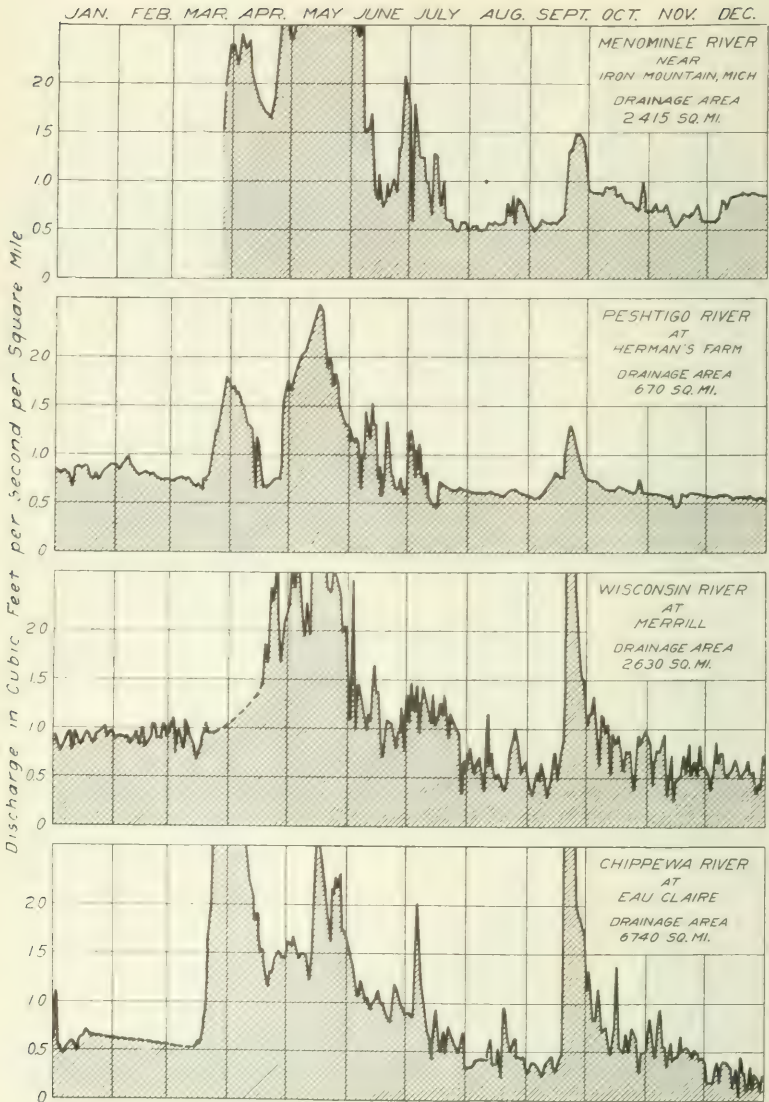


Fig. 35. Comparative Hydrographs of Flow of Four Rivers in Wisconsin, 1907.

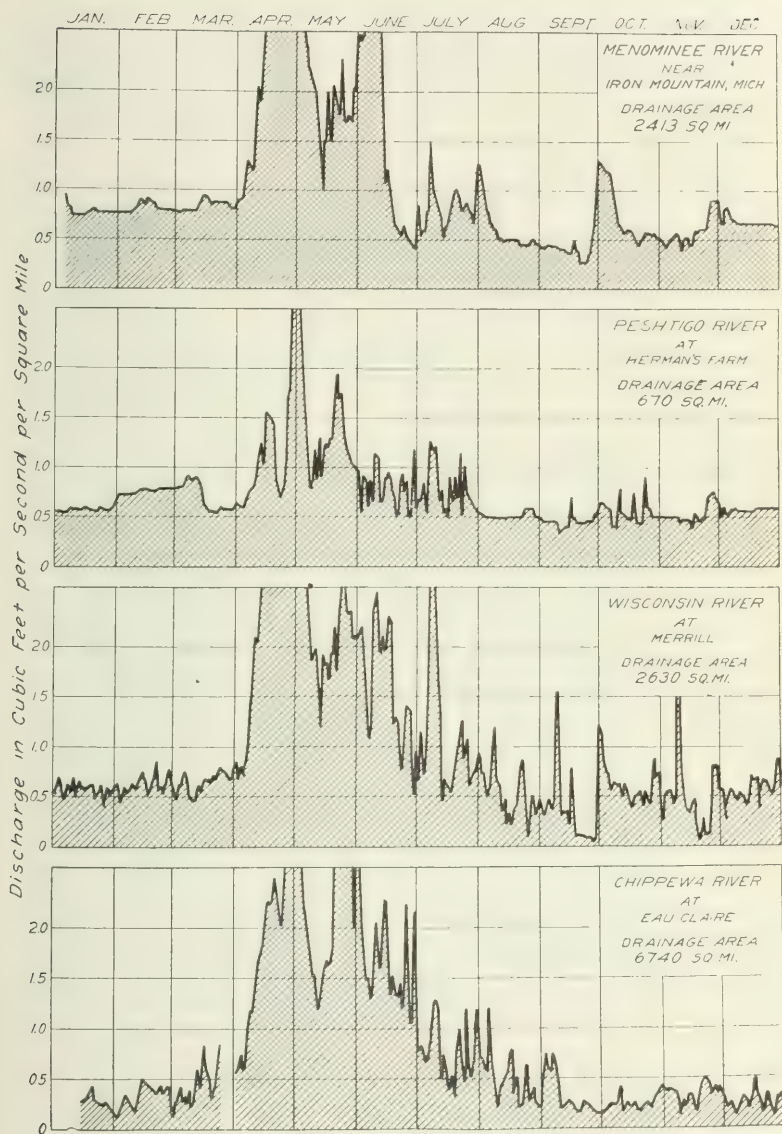


Fig. 36. Comparative Hydrographs of Flow of Four Rivers in Wisconsin, 1908.

I do not care to offer any general conclusions, but simply to call attention to the fact that it is absolutely necessary, in a determination of the limits of flood flow for which we should provide in the construction of hydraulic works, or, in determining the intensity of the run-off which may occur at times of maximum flood, that in each particular case we study and investigate the local conditions, and that only by means of such study can we hope to arrive at any

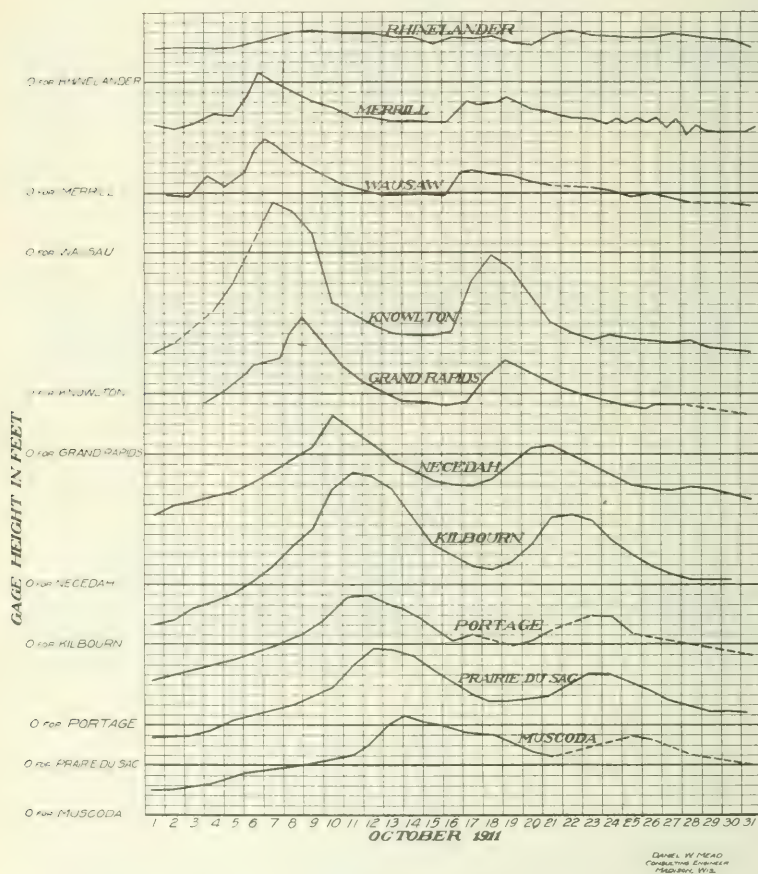


Fig. 37. Advance of Flood Wave, October, 1911.

basis that will give safe and economical results. We must take into account the rainfall conditions, the nature of the country, the character of every factor which influences the amount of run-off, and the adoption of any run-off law or run-off curve, without such study, is, I think, never excusable.

DISCUSSION.

Julius G. Gabelman, M. W. S. E.: It seems to me that the effect of the cutting of the larger trees in the forest would be offset by the rapid undergrowth of weeds and brush. I would ask Professor Mead if the forest fires in such places as along the Wisconsin River have affected the flow of the streams.

Professor Mead: I do not think they have, so far as I have been able to determine. Undoubtedly the undergrowth has the effect of replacing to a considerable extent certain influences of the forest, but not entirely. The destruction of the forest bed by the fires is a radical change in condition, but so far as we have been able to determine, there has been no change in stream flow due to this cause.

While the claim is frequently made that this forest bed when saturated is an important source of water supply, yet I know of no case where an engineer has advised going to a forest bed to secure a water supply for any purpose. We may secure a large amount of water from sands, gravels, and swamps, but who ever heard of a forest bed utilized as a source of supply. We may find a forest damp, or even wet, but I have never seen any large amount of water that could by its retention and slow delivery materially add to the regularity of stream flow or prevent floods on the streams. I believe that necessarily vegetation on a watershed may sometimes have more or less of an important effect. I believe that on a stream with an abrupt, rocky character drainage area we would find the greatest effect from vegetation and from reforestation; but on many other streams, I believe the effect of vegetation would be adverse. In general, I can only say that so far as the Wisconsin streams which I have examined are concerned, I have found no visible effects in stream flow due to deforestation. Vegetation undoubtedly has an effect on flow, sometimes favorable, sometimes adverse. If all vegetation were destroyed on most of the drainage area of the Peshtigo River, there would probably be a better equalization of flow than now obtains, because this area is a big sand plain where the water is stored and which will give a uniform flow that can be obtained in no other way. In other places, forest conditions may have a different effect, and I should be surprised if, when we investigate all of the streams of the United States, we do not find some favorable effect of forests on the flow of streams; I do not believe, however, that in any cases the forests have the marked effect that the foresters claim.

In some of the eastern states, where farms have been abandoned and have reverted back to the forest, the investigations which have been made by the United States Army engineers show no increase in flow or reduction in floods. The flow of the Merrimac River, where reforestation has taken place, and where records are available for many years, shows absolutely no signs of any radical change in the flow of the stream or decrease in the floods, which

could be attributed to the very large increase in the percentage of forest on that large area in the last 30 years.

Burton J. Ashley, M. W. S. E.: I recall going with my father in my boyhood days to an old mill which was run by means of an overshot water wheel. The water came to this mill in a stream from a large area of black ash forest, in which there were swamps to some considerable extent. As far as I remember, the stream contained water most of the year, sufficient to operate the mill, although I think the mill did not run all the time. Today that territory is largely cleared. The mill was abandoned 20 or 25 years ago because of the lack of water. That stream I believe does not now exist. At any rate, if there is a stream still there, it is simply a small covered farm drain, and I doubt whether any water runs from this vast area through it, except during rainy seasons. Passing over the road some three or four years ago, when I revisited my old home, I contemplated the conditions that I remember many years ago, and mentally compared them with what I saw. The hasty conclusion to which I came was this: That in the earlier years when this stream was in existence the ground was covered with a growing forest in a saturated soil; that there was held there in the soil and forest mulch a reservoir of water which did not evaporate because of the canopy of trees above, thereby limiting the water waste; that after clearing had taken place, and the ground became open farm land, evaporation gradually diminished the water supply until it practically disappeared. Whether I am right in my conclusions, or not, I do not know. I am simply reciting some facts which came under my observation.

Mr. Burdick: I might offer the suggestion that the things seen in boyhood viewed again in manhood look quite different. A river looks larger, viewed from the height of three feet, than it does from the height of six feet. I noticed this recently, in going back to my home town and looking at Rock River. When I visited the place where I used to go swimming I was amazed at the narrowness of the river as compared to the way the river used to look when I first learned to swim across it. I have lately had an opportunity to look at the hydrographs of that same river covering a long period, and if there is any material difference in the flow of the stream today and 15 or 20 years ago, the records do not show it.

Mr. Ashley: Mr. Burdick is quite right. As a boy I saw a stream of water large enough to run a mill, and a small bridge spanning the stream, and a mill in operation. Thirty years later I saw no stream, no bridge, and the old mill in the final stages of decay. This case was surely not one of visual aberration. In Mr. Burdick's case, the river was amply large for him to swim in when a boy, but he has grown to be a man, great in many things, now, and naturally the old swimming hole would not look large enough to accommodate him.

Clinton B. Stewart, M. W. S. E.: Referring to the relation of

forests to run-off, it seems to me that the problem is complicated by the effect of changes in agricultural conditions, such as clearing of the land, changing the surface of the land, putting in drains and especially large drains by drainage districts.

I have recently been making a study of the flood flow of the upper Wisconsin River above Merrill and have had to estimate the probable effect on flood flow from the clearing of the land and other changes in agricultural conditions. The land is now in a condition called burnt-over land, grown up with second growth timber and practically forested as far as surface conditions are concerned. When the logs and underbrush are left and second growth timber appears, I believe the flood flow will not be materially changed from that which occurs with a forest cover, but when the land is cleared and changes due to agriculture occur, I believe systematic long-time records will show considerable difference in the flood flow.

J. W. Alvord, M. W. S. E.: I had occasion at one time to search the early records of the Illinois and Michigan Canal, and found a report which the original canal engineers of that work had made on the capacity of the Fox River to feed the Ottawa level of the canal. The statement was made, if I recall it correctly, that as a result of about three years' observations prior to 1848 the low-water flow of the Fox River could be depended on to be not less than 36,000 cu. ft. per minute. Some nine or ten years ago, in connection with some litigation over water powers at the mouth of the Fox River, I had occasion to spend a large part of one summer measuring the low-water flow of the Fox River, and it got down during the course of my measurements to about 9,000 cu. ft. per minute, or about one-fourth of the amount stated by the canal engineers some 50 years before.

I have often wondered if that apparent difference, covering, as it did, the period of early settlement, later improvements and drainage, and the final clearing and planting of the Fox River Valley, may not have been more or less representative of a change from virgin conditions to a settled district which may have produced the effects noted. Of course, there may have been other factors. The character of the measurements of the original engineers as to completeness, or whether they were assumptions as to extreme low or only average low flows, is not clearly stated in the record. But it seems to me that it must have been an important question for them to have determined, because they were depending for the success of the canal on the ability of the Fox River to feed that particular level.

Mr. Burdick: One point occurred to me in connection with Professor Mead's discussion of the run-off, that was not emphasized as much as, perhaps, it should be,—namely, the condition of the ground surface as to whether it is free or frozen. In the *Journal of this Society* (Vol. I, No. 3, June, 1896), is a paper by

the late Thomas T. Johnston, entitled "Data Pertaining to Rainfall and Stream Flow," which gives quite a complete record of the run-off in the Desplaines River, and in that paper is recorded, I think, the maximum flood that has occurred upon that river,—about 22 second feet per square mile. The drainage area was also quite accurately described. To the southeast of Chicago we have the Calumet River, nearly the same drainage area but having a very different character of surface, a surface which delivers practically no water except by seepage, except in the spring of the year or at such time of the year as the ground is frozen and a rainfall occurs on that frozen ground. Such information as we have in reference to the Calumet River shows a maximum run-off per square mile essentially the same as the Des Plaines River, a watershed of very different character.

Everything that Professor Mead has said tonight emphasizes the necessity of recording just as many maximums as possible on as many different streams of as many different areas in as many different parts of the country as we can. I had hoped that in the discussion of this paper we would accumulate a few data at least upon some watersheds upon which no data have yet been published, so that when we take up any particular case we would be more likely to find some actual information upon that stream, or as close as possible to that stream, helping us to solve these problems and to prevent depending so largely upon the theoretical calculation of these floods as we must do in the absence of any data whatever.

Professor Mead perhaps did not point out the very extreme variation in flood flows in the different parts of the country. His talk was largely in reference to the flood flows in this particular locality. I have recently had an opportunity to look into a flow record covering about 25 years of daily observations upon a Kentucky stream, in which the maximum flood recorded was about 175 second feet per square mile. We have also in the past year had occasion to look into a stream in Oklahoma, the North Canadian River, with a drainage area of 10,000 square miles, that has a run-off varying from year to year between $\frac{1}{8}$ in. and $\frac{3}{8}$ in. per annum, and a maximum flood flow of 4,000 second feet total on 10,000 square miles, or 0.4 second feet per square mile. I presume, in fact I know, that the maximum on streams in the various parts of the country vary between wider limits than these. There are some streams that come down to the Mississippi—short streams—that I understand run to exceed 500 second feet per square mile, and I have no doubt that in arid regions there are streams that flow less water than the North Canadian River.

Jesse Lowe, M. W. S. E.: I have been very much interested and entertained by Professor Mead's paper. I regard it, however, as local to Wisconsin. Conditions that obtain in Wisconsin are very different from those that obtain in Illinois. From my personal knowledge of the state of Wisconsin, where I have been fishing

and hunting, it is a sandy country. In Wisconsin there are sand beds that store water, while in this state there are not. So conditions in different parts of the country are very different.

I think Professor Mead struck the keynote when he spoke of the fact that these matters should be observed for the benefit and knowledge of all, and that federal supervision and recording of the run-off, and the conditions under which the run-off took place should be carried out annually and a record maintained to which we can all have access. I believe it is the duty of the Government and not any individual to do it, and any individual who undertakes to follow out what another has done, or who takes what the oldest inhabitant gives him, is not getting anything of value. The point which the author makes, that the federal government should observe these things and give us some definite, available records, is a good one, and I think that each one of us should work to that end. Our states will not do it, nor will each individual state. Wisconsin is doing a great deal for drainage, and a great deal in the engineering line, while Illinois is not doing so well.

Referring to the floods of 1911, in my own locality in Illinois there was a rainfall of 14 in. in 30 days. During the last year I think we had the largest number of floods in the Illinois River that has ever been known. So, unexpected conditions may occur at any time, and we must make records, and the only fellow that will ever keep public records is Uncle Sam.

Professor Mead: It was my purpose to confine my remarks to a rather restricted area and show the very great variations in the run-off that occur in such an area where conditions are somewhat similar, rather than to cover the broader area of the United States, where the difference in conditions is so very great, in order to show the need of study of each particular problem, such study for example as Mr. Stewart has made on the upper Wisconsin River.

In regard to changes in hydrological conditions that have apparently taken place, as mentioned by Mr. Alvord and Mr. Ashley, I would say I have no doubt that changes do take place in the flow of streams. About three weeks ago I met Professor Moore, Director of the U. S. Weather Bureau at Washington, and in discussing some of these matters, Professor Moore spoke of a visit he made some years ago to Devils Lake, in the Dakotas. He said that a gentleman pointed out a spot and said, "The lake formerly extended all through this portion of what is now our city, and here is a place where we used to go in swimming, but the lake has shrunk; we never have water up here at the present time. What is the reason for this change?" Professor Moore replied, "In former times the whole country around the lake was uncultivated and trodden hard by the feet of the buffalo. It was more or less impervious in its nature, and the rains that fell, especially the heavy rains, simply ran off and created a lake of considerable magnitude.

For miles around the lake there are now cultivated farms; the soil has been broken and is cultivated, so that the rains may readily seep into the ground, and the amount of surface run-off has undoubtedly decreased and the lake has shrunk and probably will continue in its present condition until such time as farming may cease in that community."

Now, such changes do take place. Sometimes they take place simply through a change in the rainfall for a certain series of years. Such a change has been made manifest in an attempt to reclaim one of the old lake areas in California which was dry and was farmed at one time, but which has again become a lake on account of the temporary periodic increase in the annual rainfall. I have no doubt that the Fox River and other rivers have changed to a greater or less extent due to the cultivation of the lands in their valleys.

I do not think the forests themselves in general have the influence which they are given credit for by the foresters. I do think that there are other changes which occur, as Mr. Stewart suggests, which have important influences. The draining of swamps and other wet lands, and the cultivation of the fields, undoubtedly have sometimes affected the immediate hydrological conditions, and a great many small brooks may have ceased to run. In some cases, springs have dried up because there were no swamps to feed them. In a great many cases, however, some of the decrease in the flow of springs and streams is, I think, more or less imaginary. A small hydraulic plant is perhaps built upon a stream and, as the demand for power was originally small, its flow was sufficient for power purposes; as the demands for power increase, the deficiency in the supply becomes manifest and the power is then missed which perhaps never existed. Many of the water powers in northern Wisconsin at the present time are developed about up to the minimum flow of the stream. They have all the water they need. If a greater demand for power arises, the lack of water at the low water season will be manifest.

To draw correct conclusions, we need a great many more records of actual facts. There should be much more work of stream measurements done by our states. Colorado is doing much work in the way of gaging streams in connection with the United States Geological Survey. So are Washington, Idaho, and Oregon on a number of the western streams. We need more of this work. Individual observations recorded in papers published by our societies have their value, and I think we should all give freely the information that we gain; but continuous work of value can be done only by state and federal agencies, and such work is badly needed.

The point on which I wanted to dwell particularly is the necessity of detailed investigation of every proposition of this kind that an engineer has to meet, and the dangers in the use of formulae which apply only remotely to the conditions under consideration.

Mr. Ashley: Cannot considerable regulation be secured by reservoirs?

Mr. Mead: A considerable quantity of water is being stored in Wisconsin. Mr. Stewart has investigated this matter very much more fully than I, and can speak in more detail concerning that matter. I will say, however, that I do not think we can ever create reservoirs enough in the comparatively level land of Wisconsin to materially modify stream flow. We can help out the small water powers to a considerable extent; but the ideal hydrograph that was presented in one of the reports by the Water Supply Commission of the State of New York, where they show the flow of the Hudson River as almost fully equalized with only one or two flood peaks of insignificant size, is an ideal which may be realized under some limited conditions but which can never apply to the large rivers of Wisconsin or to other large rivers of the United States. On small streams perfect regulation is possible. Reservoirs on some of the dry runs of the West will equalize the flow, perhaps, for a good many years, because they can be built of sufficient size to catch all of the water and give it out only as it is needed; but in Wisconsin we have no great opportunities for immense reservoirs without the destruction of a great deal of valuable land, which is too valuable for that purpose. I think to a great extent the prevalent idea of our ability to regulate floods by the construction of great reservoirs is a mistake. We can get great benefits by intelligent reservoir construction; but there is a limit, and that limit is very far short of the limit described in the popular magazines.

INVESTIGATION OF FLOOD FLOW ON THE WATERSHED OF THE UPPER WISCONSIN RIVER—MERRILL AND ABOVE

CLINTON B. STEWART, M. W. S. E.

CHARACTER OF SOIL AND TOPOGRAPHY.

The portion of the watershed on the Wisconsin River considered is located at and above Merrill in Vilas, Oneida, and Lincoln counties and is shown by Fig. 1. The soil of these counties consists of glacial drifts of porous, sandy material varying from pure sand in some places to sand mixed with a slight amount of clay in others. The land is more or less rolling, but the slopes are gradual with variations in elevation not exceeding about 100 ft.

The general slope of the river valley from its source at Lake Vieux Desert to Merrill is about 3 ft. per mile. The approximate slope for the various reaches of the river and valley are shown in tabulated form. In the reach from Tomahawk to Merrill the average slope of the valley is about $6\frac{1}{2}$ ft. per mile. The fall of the river, however, is mostly concentrated at several points, leaving the effective slope of the river for stream flow about 1.3 ft. per mile. From Otter Rapids to Rhinelander the slope of the river and valley is quite small, averaging about 0.3 ft. per mile.

The bed of the main stream is well defined in the greater part of its course, but the tributaries are frequently bordered by and have their source in lakes and marshes. About 75% of the land is high and rolling. The land in general slopes toward the river with slopes of about 10 ft. per mile. In the lower part of the valley these slopes are gradual, while near the headwaters the high lands are interspersed with circular or elongated valleys which are occupied by lakes with or without outlets.

The land is almost entirely cut over land with second growth timber, about one-half of the land having been burned over in the last three or four years.

About 19 of the natural lakes, having a total area of water surface of about 50 square miles and a tributary drainage area of about 580 square miles, have been made into storage reservoirs by means of dams at the outlets of the lakes, and are at present used by the Wisconsin Valley Improvement Company for storage of flood waters for stream flow regulation, for the benefit of water power plants along the Wisconsin River.

Fig. 1 shows the location, size, and capacity of the most important of these reservoirs. Rice Storage Reservoir located on the Tomahawk River just above Tomahawk has recently been completed, and intercepts a drainage area of about 600 square miles.

STUDY OF MAXIMUM RAINFALL CONDITIONS.

In order to determine about what maximum rainfall condition should be anticipated in connection with the study of flood flow, an

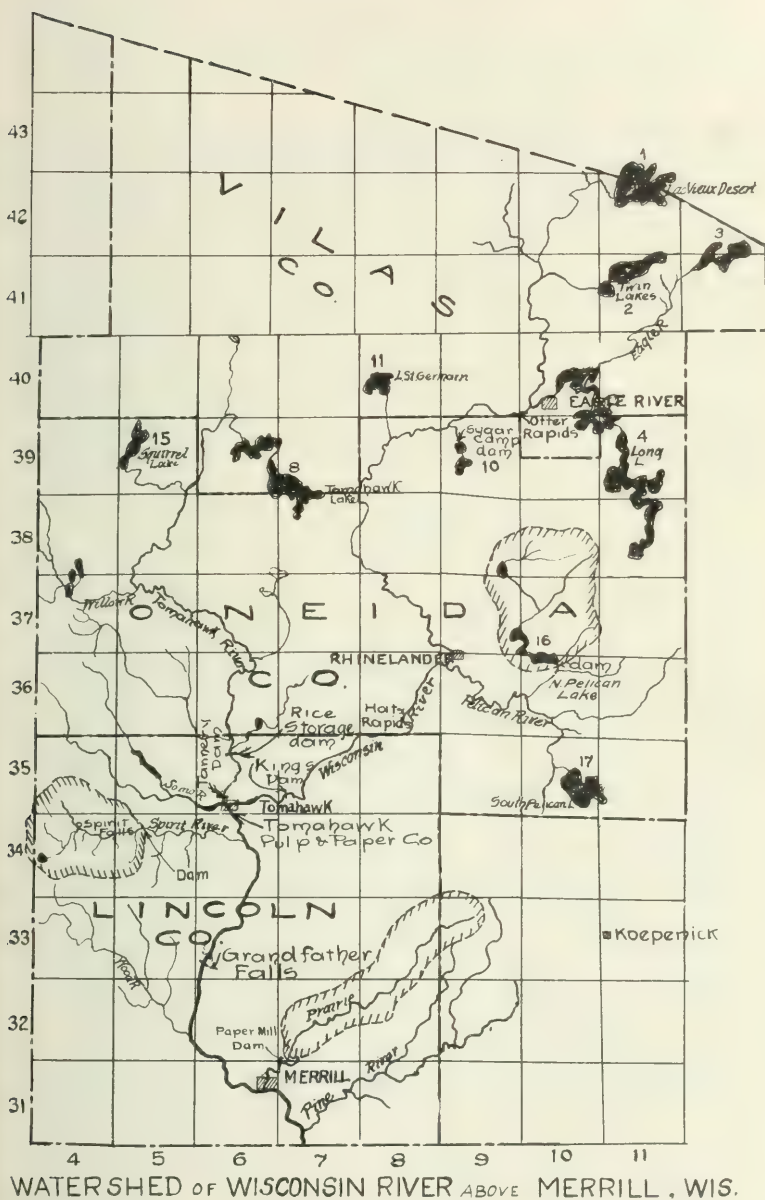


Fig. 1.

investigation was made of all of the available U. S. Weather Bureau records of the states of Wisconsin, Iowa, and northern Illinois. These records date from about 1870, and for a few stations cover a period of about 40 years, but for the majority of stations the period covered is about 10 years.

Table Showing Approximate Slope of Upper Wisconsin River

Section of River	Distance in Miles	Fall in Feet	Slope Ft. per Mile	Remarks
Wisconsin River—				
Vieux Desert to Otter Rapids	36	65	1.8	Slope of River Valley
Otter Rapids to Rhinelander	35	12	0.3	" " " "
Rhinelander to Tomahawk	30	97 54	3.2 1.8	General slope of valley omitting H. Rapid = 20 miles .23
Tomahawk to Merrill	26	173 33	6.5 1.3	General slope of valley omitting Grandmother Upper Grandfather Lower " " Bill Cross 21 33 60 26
Tomahawk River	60	121 92	2.0 1.5	General slope of valley omitting Tannery Rice Storage 14 15
Vieux Desert to Merrill	127	406	3.0	General slope of valley

TABLE I.
AVERAGE RAINFALL IN INCHES
ON THE
WATERSHED OF THE UPPER WISCONSIN RIVER
MERRILL AND ABOVE

Year	Jan	Feb	Mar.	Apr	May	June	July	Aug	Sept	Oct*	Nov	Dec	Total
1896	0.95	0.41	1.03	3.06	4.72	1.83	3.04	4.13	2.17	2.88	4.11	1.20	29.53
1897	.40	1.36	2.21	1.11	2.07	4.92	3.18	1.70	2.50	2.98	1.31	0.56	25.30
1898	0.65	1.80	1.60	1.70	2.49	4.01	2.67	1.33	2.47	2.82	1.94	0.29	23.77
1899	0.69	0.86	2.38	3.33	3.98	3.79	2.20	3.25	3.20	4.78	0.42	1.79	30.87
1900	0.61	1.30	1.44	2.55	1.42	2.68	8.40	4.96	8.23	7.58	1.03	0.80	41.00
1901	0.80	0.77	3.90	0.65	1.77	4.28	6.79	3.47	4.59	2.28	1.45	0.61	31.36
1902	0.88	0.87	0.87	2.48	2.74	4.30	2.14	.51	1.89	2.13	4.24	1.13	25.18
1903	0.48	0.54	2.45	2.27	5.49	1.65	5.47	6.39	7.56	2.38	0.86	0.59	36.13
1904	0.40	1.34	1.62	2.08	5.86	5.78	3.54	4.36	7.05	5.43	0.29	2.45	40.20
1905	1.21	0.65	1.38	1.15	3.83	7.32	2.45	5.65	3.86	2.02	1.75	1.06	32.33
1906	1.85	0.54	2.00	1.49	4.76	5.07	2.39	4.91	2.47	2.45	2.60	1.10	31.63
1907	1.24	0.54	.45	2.25	1.23	2.61	2.81	2.61	6.65	0.73	0.52	0.52	23.16
1908	0.65	1.73	1.85	3.04	3.00	3.66	4.46	1.28	3.66	0.94	1.47	1.09	26.83
1909	0.53	1.26	1.29	2.95	2.11	3.36	5.26	2.41	2.45	1.71	4.48	0.93	28.74
1910	0.76	0.97	0.29	2.46	2.42	0.36	2.13	3.06	2.40	1.12	.12	0.83	18.94
1911	0.76	1.10	1.68	0.89	4.95	1.52	6.85	4.49	4.03	6.56	2.74	2.49	38.06
Average (1896-1911)	0.88	1.00	1.71	2.09	3.30	3.57	3.98	3.46	4.06	3.11	1.89	1.09	30.14

Systematic records of rainfall on the watershed of the upper Wisconsin River were not started until about 1896. Table I gives the average monthly rainfall in inches from this date to 1911 inclusive, as compiled from the records of the U. S. Weather Bureau and Wisconsin Valley Improvement Company by Mr. A. A. Bab-

TABLE II
RAINFALL RECORDS FOR 1911 & 1912

Records on the Upper Wisconsin River and
other points in Wisconsin and Illinois causing flood conditions.

Year 1911.

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Upper Wis Watershed													
Vu de Sare	1.48	1.83	2.72	0.36	4.32	1.44	6.50	5.98	2.89	5.21	4.03	2.80	39.26
Long Lake (Three Lakes)	0.81	1.31	1.76	0.59	4.88	1.67	6.96	4.90	2.74	6.06	1.99	2.13	35.80
Big St Germain	0.86	0.89	1.39	1.08	4.08	1.33	9.30	4.52	3.31	6.62	4.12	4.41	41.91
Rhinelanders	0.66	1.17	1.46	1.18	5.89	2.45	9.31	3.29	4.45	8.87	1.72	1.97	42.12
Merrill, Wis.	—	1.16	—	—	—	1.90	5.69	2.54	7.24	8.77	2.23	2.91	
Black River Watershed													
Stanley	0.91	0.94	1.04	0.91	4.60	4.02	5.32	2.42	6.04	10.02	1.98	1.81	40.03
Chippewa River Watershed													
Eau Claire	1.11	1.41	1.34	0.91	5.52	6.74	4.13	2.59	6.22	10.35	1.79	2.40	44.51
Neillsville	1.10	1.52	1.87	1.66	7.56	6.49	3.81	3.90	8.11	8.40	1.42	3.03	48.87
Illinois River Watershed													
Lincoln, Ill.	2.45	1.91	2.32	3.76	1.79	2.43	1.57	2.97	14.31	2.43	1.59	2.31	39.90
Miss River Watershed													
Monmouth, Ill.	2.53	3.51	2.25	4.12	1.53	2.05	4.12	1.70	20.03	2.38	3.00	1.90	49.12

Year 1912.

Upper Wis. Watershed													
Merrill, Wis.	.20	Approx. 0.19	0.15	4.49	7.19	1.20	15.26						
Wausau, Wis.	0.38	0.06	0.59	3.10	5.28	0.56	9.63						

DAILY RAINFALL RECORD FOR JULY 1912.

STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Merrill, Wis.				95	.13			60					90	80									59.05.35					.31		13	19
Wausau, Wis.	23	.19	.53	.20		.13			82			160	.65										2.002.50							.53	.25

* Caused flood conditions.

cock, engineer of the improvement company. It will be noted that the average annual rainfall for the watershed above Merrill, for the 16-year period, amounts to about 30 in. The maximum rainfall for any one year for the whole watershed has been 41.0 in. in 1900. The maximum annual rainfall for any one station on this watershed has been 42.12 in. at Rhinelander, in 1911. (See Table II.) The heaviest rainfalls occur in the summer and fall of the year, the maximum for any one month during the 16-year period, 1896-1911, having been 9.31 in. for July, 1911, at Rhinelander.

Since the completion of this investigation (June, 1912) an extraordinary rainfall has occurred at Merrill, Wisconsin, on July 23rd and 24th, 1912, amounting on these dates to 5.90 in. and 5.35 in. respectively, and all of which 11.24 in. fell in a 24-hour period (Table II) for monthly and daily records. The rainfall at Wausau was 4.50 in. in 24 hours. From a study of the rainfall records at other adjoining towns, Prentice 5.09 in., Medford 2.65 in., Rhinelander 1.16 in., Koepenik 3.20 in., and Antigo 6.03 in., it seems probable that a rainfall of 5 in. or more in 24 hours extended over an area of about 1,000 square miles. In the immediate vicinity of Merrill it is probable that a rainfall of 10 in. or more in 24 hours extended over an area of about 200 square miles. This storm caused the failure of a number of dams and large property loss in the vicinity of Merrill and Wausau. (See *Engineering News*, August 8, 1912.)

The rainfalls of October 3-6th, 1911, in north central Wisconsin, which, together with heavy rains previous to this, caused extreme flood conditions, are the heaviest on record in this state as to area covered. Figures 2, 3 and 4 bring out the important features of this storm. The areas covered by the rainfall of various amounts, for periods of 2, 4 and 10 days, are shown by contours. It will be seen that the storm center was at Stanley, Wisconsin, on the headwaters of the Eau Claire River (Chippewa watershed), and only a portion of the storm extended eastward to the Wisconsin watershed. In this latter watershed the heaviest rainfall was at Merrill and Wausau, being equal to about three-quarters of that at the storm center. It will be noticed that the direction of the storm was from west to east and extended from the western part of Minnesota. The rainfall gradually decreased at stations up-stream from Merrill, and at the headwaters, Lake Vieux Desert, was about one-half that at Merrill.

On September 24th and 25th, 1911, a very heavy rainfall occurred in the neighborhood of Monmouth and Lincoln, Illinois. Figures 5 and 6 show the areas covered in 2 and 10 day periods. This rainfall was more severe than that of October 3-6th in Wisconsin and a rainfall of 5 in. or more in two days extended over 2900 square miles; 4 in. or more in two days extended over 5550 square miles. A comparison of the two storms is shown by Table III. Additional data are also shown concerning a heavy rain-

fall in the vicinity of Chicago, September 3-10th, 1894, in which an average of 1 in. of rain per day fell for seven days covering about 1000 square miles.* On October 4th, 1869, a great storm occurred in Connecticut, which is probably the greatest on record as to extent of area covered by heavy rainfalls. The details of this storm as summarized by Mr. J. B. Francis in *Transactions of the American Society of Civil Engineers*, Vol. VII, are given in the footnote of Table III. About seven days previous to this storm a rainfall of about 3 in. had occurred, and was preceded by other smaller rains of average amounts distributed through the month of September.

The diagram, Plate I, shows a comparison of the various

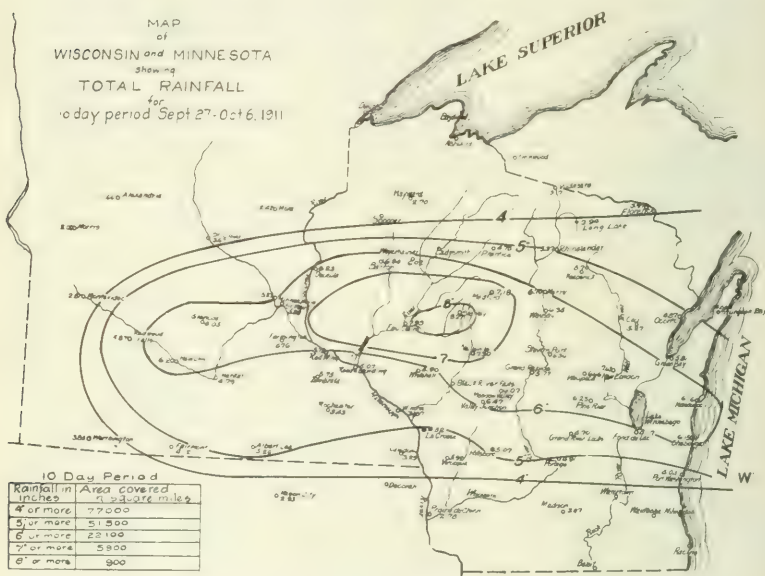


Fig. 4.

rainfalls considered, together with the conclusions reached as to probable maximum rainfall conditions. On this diagram the total rainfall for periods of from 1 to 30 days is given for each station considered. The period of time in each case is chosen so as to end with a final, heavy rainfall, which in general would produce flood flow. For example, for Merrill, Wis., for the one day ending October 6th, a rainfall of 3 in. occurred; for a period of three days, ending with October 6th, the same amount of rainfall had occurred; for the period of four days, ending October 6th, a rainfall of $4\frac{1}{2}$ in. occurred while for the period of 30 days ending October

*See reference to this rainfall by Mr. T. T. Johnston in *Journal Western Society of Engineers*, Vol. 1, 1896.

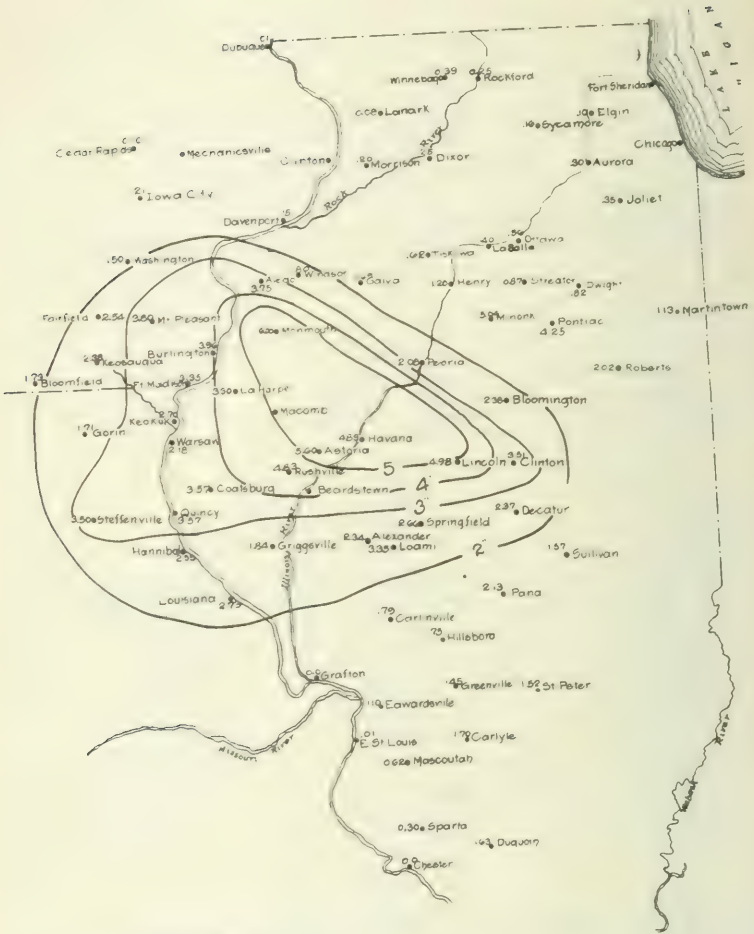
TABLE III.
SUMMARY OF MAXIMUM RAINFALL CONDITIONS
ILLINOIS, IOWA & WISCONSIN
U.S. Weather Bureau Records 1870-1911

Rainfall in inches	Approximate area in sq. miles covered by Storm.	
For 2 day period	Stanley Wis. Oct. 5 & 6, 1911 (illus. by Pl.)	Monmouth Ill. Sept. 24 & 25, 1911 (illus. by Pl.)
2" or more	58 000	21 200
3" " "	18 000	11 600
4" " "	3 100	5 500
5" " "		2 900
For 4 day period	Stanley Wis. Oct. 3, 4, 5 & 6, 1911 (illus. by Pl.)	
3" or more	50 000	
4" " "	30 800	
5" " "	10 800	
6" " "	600	
For 10 day period	Stanley Wis. Sept. 27-Oct. 6, 1911 (illus. by Pl.)	Monmouth Ill. Sept. 24-Oct. 3, 1911 (illus. by Pl.)
5" or more	51 500	25 500
6" " "	22 100	20 000
7" " "	5 900	11 400
8" " "	900	6 500
9" " "		4 600
10" " "		3 000
For 7 day period	Chicago Ill. Sept. 3-10, 1894	
6" or more	3080	
7" " "	1000	

NOTE:—Oct. 4, 1869 a great storm occurred in Connecticut covering about 2 days, concerning which Mr. J. B. Francis gives the following data in Vol. VIII of the Trans. Am. Soc. Civil Engineers.

Depth of Rain	Area covered
6" or more	24431 sq. mi.
8" " "	1824 " "
10" " "	519 " "
11" " "	179 " "

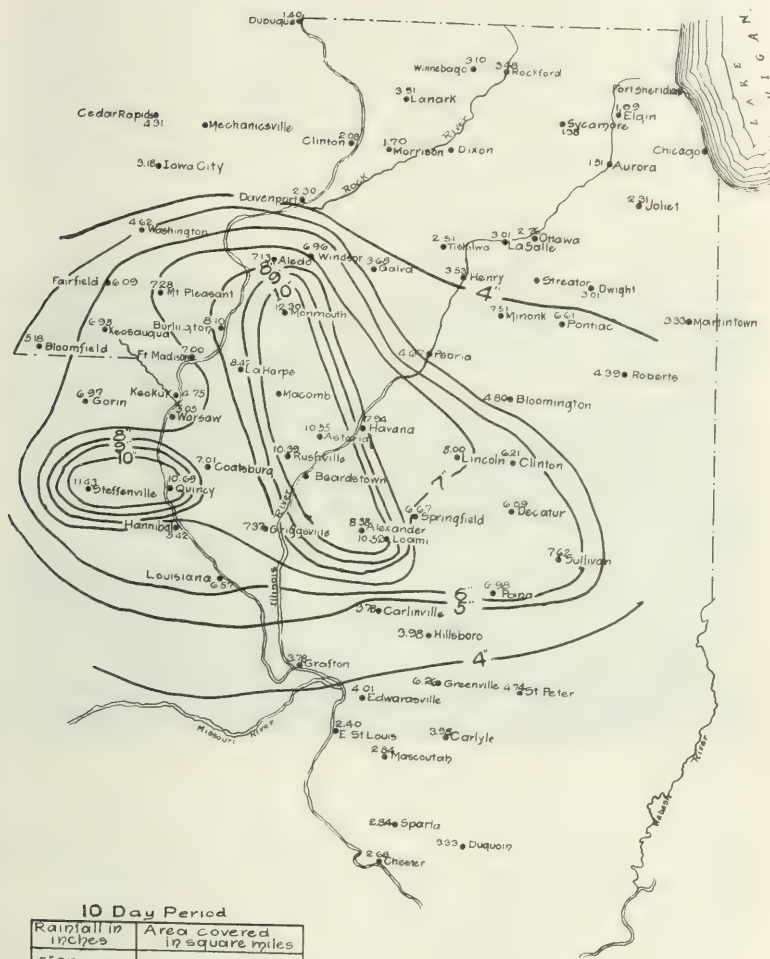
The average annual rainfall for Connecticut is about 45" while that of Wisconsin is about 32"



2 Day Period	
Rainfall in inches	Area covered in square miles
2' or more	21200
3' or more	11600
4' or more	5500
5' or more	2900

MAP
of
ILLINOIS
showing
TOTAL RAINFALL
for
Sept. 24 & 25, 1911

Fig. 5.



10 Day Period	
Rainfall in inches	Area covered in square miles
5" or more	25500
6" or more	20000
7" or more	11400
8" or more	6500 2 Storm Centers
9" or more	4600 2 Storm Centers
10" or more	3000 2 Storm Centers (2300 + 700)

MAP
of
ILLINOIS
showing
TOTAL RAINFALL
for
10 day period Sept. 24-Oct. 3, 1911.

Fig. 6.

6th, a total of $11\frac{1}{2}$ in. had occurred. The rainfalls for the longer periods of 10-30 days show in a measure the height of the ground water table and aid the judgment in determining the effect of final heavy rains of 2 or 4 days' duration which produce flood flow. With a high ground water table and swamps full of water, heavy rains will produce flood flow. With only slight rains during the preceding 10 and 30 days, the swamps and soil will be capable of absorbing and holding in storage a large part of the rainfall.

The general conclusion as to the maximum rainfall conditions which it is reasonable to expect, at any given place, probably not



Fig. 7. Flood at Merrill, Wis., July 24, 1912. Water Washing Around the Dam.

exceeding about once in 50 years, is shown by the three curves marked Nos. 1, 2 and 3, Plate I, and summarized below.

PROBABLE MAXIMUM RAINFALL CONDITIONS ABOUT ONCE IN 50 YEARS.

Time Period in Days	Inches of Rainfall for Specified Areas in Square Miles		
	500	1000	2500
2	10	8	6
4	11	9	7
10	13	$11\frac{1}{2}$	10
30	15	14	13

The rainfall conditions specified for 2500 square miles, curve No. 1, have practically occurred in the Monmouth storm ending

September 25, 1911. Rainfalls of 10 in. in one and two day periods have occurred at Merrill, Butternut, and Medford, Wisconsin, and also at a number of stations in Iowa and Illinois, which have not been shown on the plate. Reliable information of the areas covered by these heavy rainfalls cannot be obtained. In the Connecticut storm of October, 1869, Mr. J. B. Francis records that 10 in. of rain extended over 519 square miles. In the storm at Merrill, Wis., July 23rd and 24th, 1912, it is probable that 10 in. of rain fell in a

TABLE IV
SHOWING RELATION OF PONDAGE TO FLOOD
FLOW AND SLUICE GATE CAPACITY OF
VARIOUS RESERVOIRS AND POWER
PLANTS, UPPER WISCONSIN RIVER.

Name of Reservoir or Plant.	Rel. No.	Drainage Area in sq. mi.	Res. & Pond Area sq. mi.	Width of Sluice ft.	Approx. Depth in Sluices for Condition,		Storage to H.W. Mark Mill cu. ft.	Storage Gap to top of dikes Mill cu. ft.	Disch. Cap. at H.W. & top of dikes cu. ft./sec. per sq. mi.		Assumed Flood Flow cu. ft./sec. per sq. mi.	Time req. for water to rise from H.W. to top of dikes with gales open and assumed flood flow
					High Water	Top of Dikes			HW	Top of Dikes		
Vieux Desert	1	28	7½	16.0	4.0	5.0	750	950	12	17	30 20	5.5 days 16.0
Sugar Camp	2	60	5	11.5	7.0	8.0	700	850	9	11	30 20	1.3 days 2.6 "
Big St. Germain	3	64	2½	11.0	3.5	5.0	200	300	3.0	5.8	30 20 10	0.7 days 1.0 " 2.7 "
Burnt Rollways Long on Eagle	4	120	6¾	22	5.0	7½	570	1040	60	11.2	30 20	2.1 days 4.0 "
Rice Storage	5	600	7	60	15	21	1500	2500	155	280	50 40	14 hrs. 20 "
Otter Rapids	6	475	5.0	48	8.5	15.5	800	1800	74	18	40 30	21 hrs. 33 "
Rhineland Paper Co.	7	800	5.0	20	10.5	13	800	1150	4.9	6.7	30 20 10	5 hrs. 8 " 27 "
King's Plant	8	1200	30	60	15	18	400	650	10.6	13.5	30 20	3.5 hrs. 7 "
Tomahawk Pulp & Paper Co.	9	1900	3.75	—	12.5	14	700	860	13.7	17.5	20	5 hrs.

No's 1-5 are Reservoirs
" 6-9 " Water Power Plants.

24-hour period, and extended over an area of at least 200 square miles.

Mr. Archibald Johnson, U. S. Assistant Engineer, in a report describing the flood of 1884 at Chippewa Falls (House Doc. 50th Congress, 1st Session 1887-88, Vol. IV, page 729) states: "The flood of 1884 was mainly caused by an extraordinary rainfall over a small area of watershed, and did not extend above the mouth of the Flambeau River. No reliable data are available as to the amount

of the rainfall but it is said to have varied from 10 to 19 in. in 36 hours." The area of the watershed between the mouth of the Flambeau River and Chippewa Falls is about 1740 square miles.

The curve No. 4, representing the probable maximum rainfall conditions once in 100 years, was determined by assuming the possibility of rains about 10 in. in 1 or 2 days' duration occurring in connection with rains of about 21 in. per month, as happened at Monmouth, Ill., for the period ending October 1, 1911. Such a combination of circumstances as 22 in. of rain in 30 days, and ending with 10 in. of rain in the last 1 or 2 days of the 30 days' period, may possibly occur for small drainage areas, but probably would not cover exceeding 500 square miles.

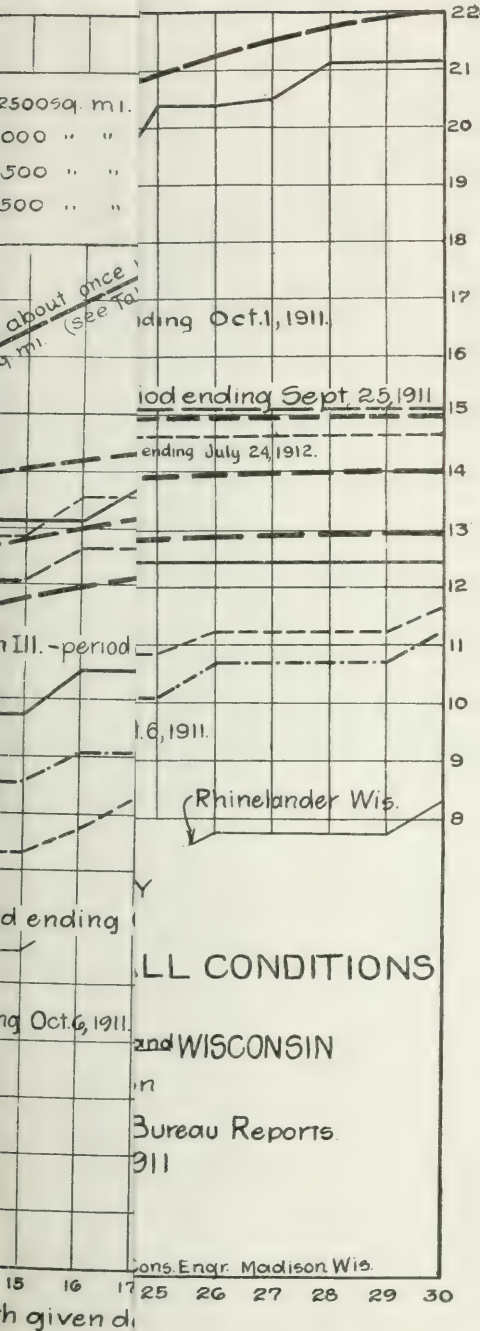
DISCUSSION OF FLOOD FLOW.

The maximum discharge of a stream depends on a great many factors, the most important of which are:

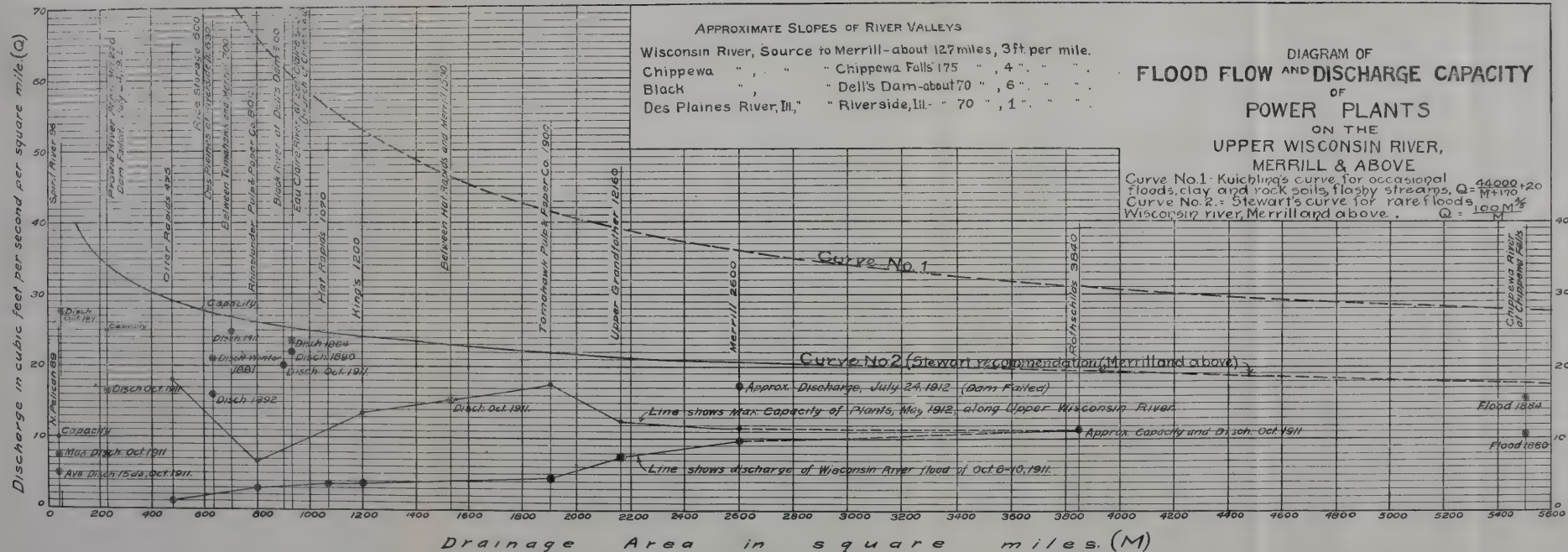
1. The amount, intensity, and distribution of the precipitation over the drainage area.
2. Character of the soil and steepness of the slopes.
3. The amount and distribution of the precipitation for a period of 10 and 30 days previous to the final rainfall producing the flood.
4. Natural and artificial storage features in the drainage basin.
5. The amount of snow on the ground which, in connection with certain temperature and rainfall conditions and frozen ground, may produce a large discharge.

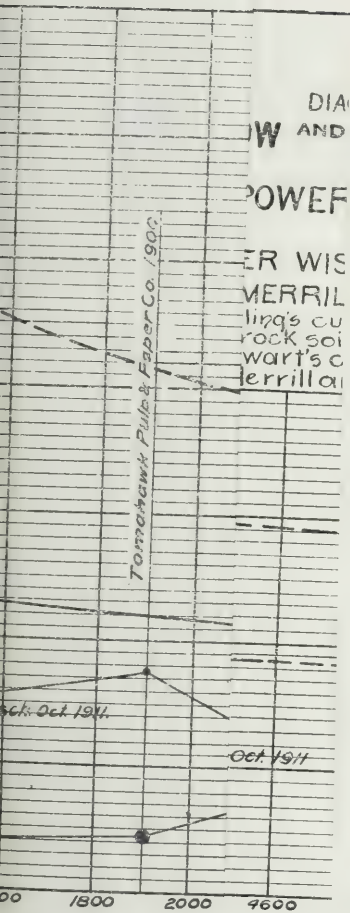
The discharge of a stream is most conveniently spoken of as the number of cubic feet per second that each square mile contributes to the flow. As the area covered by heavy rainfalls is usually limited to small areas, the discharge per square mile will, in general, increase as the drainage area decreases.

Records of stream flow have existed on the Wisconsin River at Merrill since 1903, and at Hat Rapids since 1906. On the portion of the watershed above Hat Rapids stream flow is very much modified by the reservoirs. From the records of rainfall, Table II, it seems probable that rainfall conditions have not occurred since 1896, when practically all the reservoirs were filled to high water mark, before the occurrence of a final heavy storm. In the absence of this condition reservoirs modify flood flow. If the reservoirs have limited sluice gate capacity for passing the flood flow at the high water mark, the flow through the gates will gradually increase for a period of time until the water in the reservoir reaches the top of the dikes or piers. This period of time will depend both on the flood flow into the reservoir and the outflow through the gates. If the period of time is less than the possible duration of the flood flow into the reservoir, then the reservoir will be in danger of failure. Table IV has been prepared to aid the judgment as to this period of time, for the various reservoirs and



3020





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TABLE IV
DISCHARGE CAPACITY OF POWER PLANTS AND FLOOD FLOW DATA FOR UPPER WIS. RIVER, MERRILL AND ABOVE

DISCHARGE CAPACITY OF POWER PLANTS AND FLOOD FLOW DATA FOR OFFER WATER RIGHTS														
Location	Drainage Area above Dam	Drainage Area Contributing	Discharge Capacity for Normal pond level, gates, roll & wheels		Max Disch. capacity, Water at top of piers or dikes		Max Disch. Oct. 6-10 1911	Ave. Rainfall above Dam				Rainfall		
	Sq. mi.	Sq. mi.	Cu Ft/sec	Disch. per sq. mi.	Cu Ft/sec	Disch./sq. mi.	Cu Ft/sec	Dis./sq. mi.	2 days Oct. 5-6-7	4 days Oct. 3-4-5-6-7	10 days Sept. 27-Oct. 6-11	30 days Sept. 17-Oct. 16-11	Departure from 15 yr. Ave Jan. 1, 1911 to Aug. 31, 1911	
Otter Rapids Eagle River Plant.	475		3500	7.4	8548	18.0	about 500	1.0	L = 2.17 V = 1.52 Ave = 1.84	L = 3.03 V = 2.23 Ave = 2.63	L = 3.94 V = 3.17 Ave = 3.36	L = 5.67 V = 4.62 Ave = 5.13	L = +2.50 V = +4.25 Ave = +3.97	
Rhineland Paper Co.	800		3920	4.9	5370	6.7	2300	3.0						
Rhineland Paper Co. Hat Rapids	1070		11660	10.8	12530	11.7	4000	3.7	R = 2.80 L = 2.17 V = 1.52 Ave = 2.16	R = 4.00 L = 3.03 V = 2.23 Ave = 3.09	R = 5.37 L = 3.94 V = 3.17 Ave = 4.16	R = 8.30 L = 5.67 V = 4.62 Ave = 6.20	R = +5.03 L = +2.50 V = +4.25 Ave = +3.93	
King's Plant	1200		12680	10.6	16200	13.5	4500	3.8						
Tomahawk Pulp & Paper Co.	1900		25960	13.7	33120	17.5	7900	4.2						
Rice Storage Dam	600		9300	15.5	16800	28.0								
Tannery Dam	600		1100	1.8	3760	6.3								
North Pelican River outlet N. Pelican Lake.	89				APPROX 10.0	Ave. for 15 days 450	5.0		R = 2.80 L = 2.17 V = 1.52 Ave = 2.16	R = 4.00 L = 3.03 V = 2.23 Ave = 3.09	R = 5.37 L = 3.94 V = 3.17 Ave = 4.16	R = 8.30 L = 5.67 V = 4.62 Ave = 6.20	R = +5.03 L = +2.50 V = +4.25 Ave = +3.96	
Spirit Falls Dam Spirit River	96					2600	27.5		M = 3.00 P = 2.22 Ave = 2.61	M = 4.60 P = 3.43 Ave = 4.02	M = 6.70 P = 4.70 Ave = 5.74	M = 11.76 P = 7.42 Ave = 9.39		
Prairie River at Paper Mill (Merrill)	220				5500	25.0	Oct 7-9 AM 3600	16.5	M = 3.00 K = 2.60 Ave = 2.80	M = 4.60 K = 4.10 Ave = 4.35	M = 6.70 K = 5.70 Ave = 6.20	M = 11.70 K = 9.50 Ave = 10.61		
Grandfather Falls	2160				26500	12.3	16400	7.6						
Merrill Electric Light and Ry. Co.	2600				30400	11.7	25300	9.8	Oct 6-6 PM 1.0	Min = 2.13 M = 3.00 R = 2.80 L = 2.17 V = 1.52 Ave = 2.32	Min = 3.03 M = 4.60 R = 4.00 L = 3.03 V = 2.23 Ave = 3.23	Min = 3.94 M = 6.70 R = 5.37 L = 3.94 V = 3.17 Ave = 4.63	Min = 5.67 M = 11.76 R = 8.30 L = 5.67 V = 4.62 Ave = 7.30	Min = +1.66 M = +5.03 R = +3.93 L = +2.50 V = +4.25 Ave = +3.36
Hat Rapids to Merrill		1530					22940	13.2		M = 3.00 R = 2.80 Ave = 2.90	M = 4.60 R = 4.00 Ave = 4.35	M = 6.70 R = 5.37 Ave = 6.03	M = 11.70 R = 8.30 Ave = 10.00	Min = 1.66 R = 5.03 Ave = 3.37
Tomahawk to Merrill		700					17400	24.8		M = 3.00 R = 2.80 Ave = 2.90	M = 4.60 R = 4.00 Ave = 4.35	M = 6.70 R = 5.37 Ave = 6.03	M = 11.70 R = 8.30 Ave = 10.00	Min = 1.66 R = 5.03 Ave = 3.37
Grandfather to Merrill		440					8900	20.2		M = 3.00 R = 2.80 Ave = 2.90	M = 4.60 R = 4.00 Ave = 4.35	M = 6.70 R = 5.37 Ave = 6.03	M = 11.70 R = 8.30 Ave = 10.00	Min = 1.66 R = 5.03 Ave = 3.37
Hat Rapids to Merrill		1530				(Sept. 20 1907)	11200	7.3		2 days Sept. 14-15 M = 4.80 Min = 1.20 Ave = 10.4	4 days Sept. 16-17 M = 5.32 Min = 3.93 Ave = 9.62	10 days Sept. 10-19 M = 5.44 Min = 6.99 Ave = 6.18	30 days Aug. 21-30 M = 7.26 Min = 7.98 Ave = 7.32	Jan. 1, 1907 to Aug. 31, 1907 About -4.10
Black River at Dells Dam	900					(Oct 1 1911)	APPROX 18000	20.0						
Chippewa River at Chippewa Falls	5500					(Sept. 19, 1884)	56000	15.6						
Chippewa River at Chippewa Falls	5500					(June 13, 1880)	57000	10.4						
Eau Claire River at Eau Claire	940					(Sept. 13, 1884)	APPROX 82000	23.4						
Eau Claire River at Eau Claire	940					(June 13, 1880)	20000	22.0						
Desplaines River at Riverside	630					(Winter 1881)	15500	21.0						
DAMS FAILED, JULY 24, 1913.														
Merrill Electric Light and Railway Co.	2600				30400	11.7	July 24, 1912 about 45000	17.3	July 23-24 M = 11.25 R = 1.76 Ave = 4.35	July 21-24 M = 11.25 R = 1.76 Ave = 4.35	July 15-24 M = 11.25 R = 1.76 Ave = 4.35	June 25-July 31 M = 11.25 R = 1.76 Ave = 4.35	Jan. 1, 1912 to June 31, 1912 R = +0.87	
Prairie River at Paper Mill near Merrill	220				5500	25.0	No data		11.25	11.25	12.05	14.63	+0.87	

NOTE: M represents Merrill Min.

L represents Long Lake
D. " Des Plaines
P. " PrairieR represents Koenig
RhineclanderV represents Vieux Desert
C.B. Stewart, Com. Eng., Madison, Wis.

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TABLE II
FLOOD FLOW DATA, RIVER, MERRILL AND ABOVE

Capacity of pond roll & wheels h. per sq. mi.	Max Disch. 1 above Dam		Rainfall			
	capacity, Water 5	10 days	30 days	Departure from		
	top of piers or d'n'll	Sept 27-Oct 6 '11	Sept 7-Oct 6 '11	15 yr Ave Jan 1, 1911 to		
	Cut/sec	Disch/sec		Aug. 31, 1911.		
7.4	8540.	18.0	3	L = 3.94	L = 5.67	L = +2.50
			3	V = 3.17	V = 4.62	V = +4.25
			23	Ave = 3.56	Ave = 5.15	Ave = +3.37
4.9	5370	6.7				
10.8	12530	11.7	20	R = 5.37	R = 8.30	R = +5.03
			23	L = 3.94	L = 5.67	L = +2.50
			23	V = 3.17	V = 4.62	V = +4.25
			19	Ave = 4.16	Ave = 6.20	Ave = +3.93
10.6	16200	13.5				
13.7	33120	17.5				
15.5	16800	28.0				
1.8	3760	6.3				
		APPROX		R = 5.37	R = 8.30	R = +5.03
		10.0	23	L = 3.94	L = 5.67	L = +2.50
			56	Ave = 4.66	Ave = 6.98	Ave = +3.76
			15	P = 4.78	P = 7.42	
			20	M = 6.70	M = 11.76	
			02	Ave = 5.74	Ave = 9.59	
			60	M = 6.70	M = 11.70	
	5500	25.0	10	K = 5.70	K = 9.50	
			35	Ave = 6.20	Ave = 10.61	
	26500	12.3				
			03	Min = 3.93	Min = 6.14	Min = +1.66
			60	M = 6.70	M = 11.76	M = +5.03
			09	R = 5.37	R = 8.30	R = +2.50
			23	L = 3.94	L = 5.67	L = +4.25
			23	V = 3.17	V = 4.62	V = +3.36
			28	Ave = 4.63	Ave = 7.30	Ave = +3.36
			60	M = 6.70	M = 11.70	Min = 1.66
			09	R = 5.37	R = 8.30	M = 5.03
			35	Ave = 6.03	Ave = 10.00	Ave = +3.34
			60	M = 6.70	M = 11.70	Min = 1.66
			09	R = 5.37	R = 8.30	M = 5.03
			35	Ave = 6.03	Ave = 10.00	Ave = +3.34
			60	M = 6.70	M = 11.70	
			5	10 days	30 days	Jan. 1, 1907 to
	(Sept 20 1907)	19	Sept 10-19	Aug 21-30		Aug. 31, 1907
		12	M = 5.44	M = 7.26		About -4 10
		23	Min = 6.93	Min = 7.58		
		23	Ave = 6.18	Ave = 7.22		
	(Oct 1 1911)					
	(Sept. 10, 1888)					
	(June 13, 1888)					
	(Sept 10, 1888)					
	(June 13, 1888)					
	(Winter 1888)					
DAMS FAILED						
	30400	11.7	24	July 15-24	June 25-July 24	Jan. 1, 1912 to
			25	M = 12.05	M = 14.63	June 31, 1912
			16	A = 1.96	A = 3.75	M = +0.87
			61	L = 0.80	L = 2.10	
			34	Ave = 4.84	Ave = 6.83	
	5500	25.025	12.05	14.63		+0.87

336A

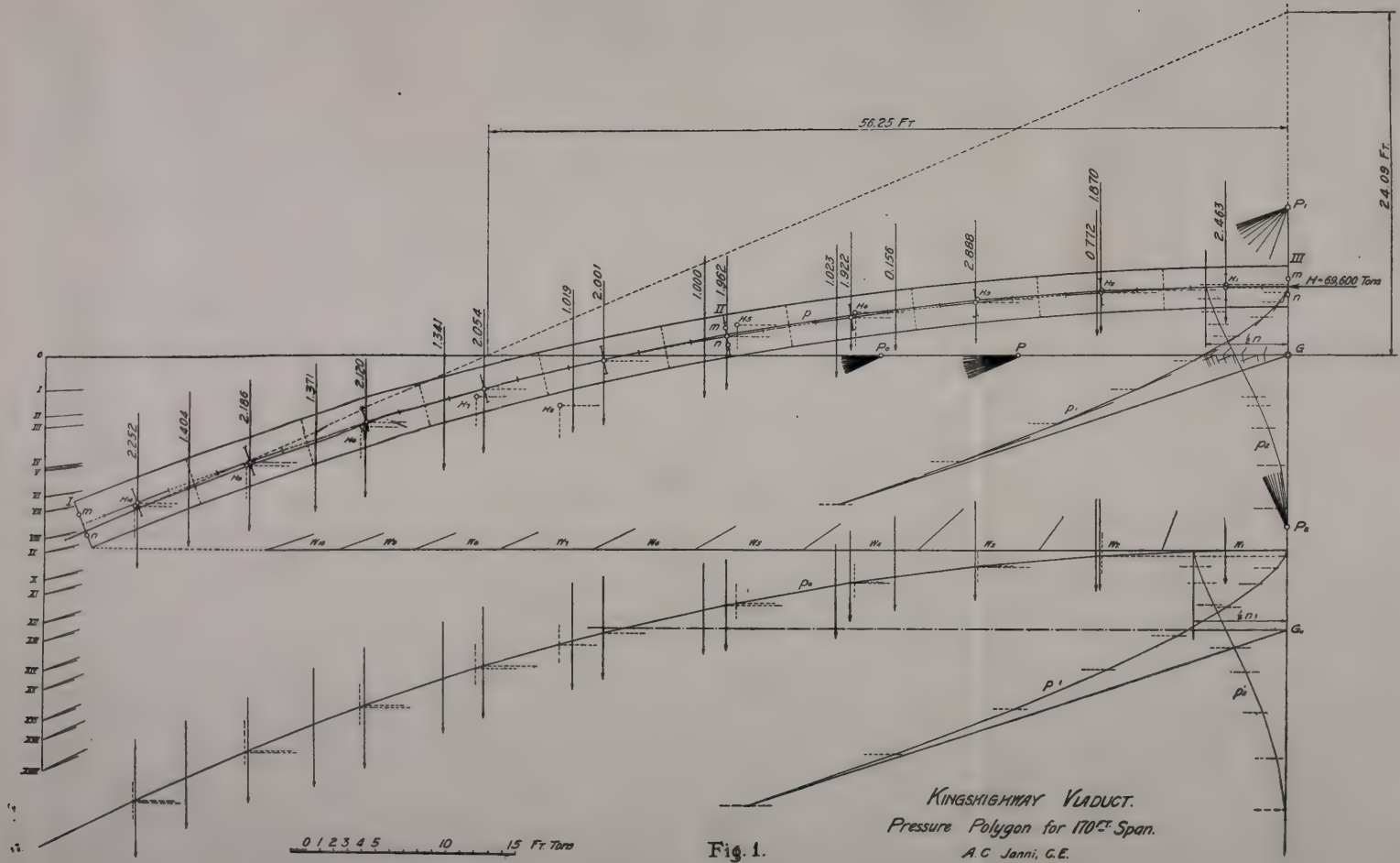


Fig. 1.

power plants given, for certain assumed rates of flood flow. Assuming that a flood flow of 30 cu. ft. per second per square mile is possible, the table shows that Vieux Desert would be safe for 5.5 days, Sugar Camp for 1.3 days, and Big Saint Germain for 0.7 days. These time periods, when considered in connection with the probability of the assumed rate and duration of flood flow, at each point considered, will aid the judgment as to determining the flood risk at each reservoir or power plant.

The storm ending October 6th, 1911, together with previous rainfall conditions, resulted in very serious flood flows over a large part of the state of Wisconsin. The flood flow at Merrill, as indicated by the gauge readings at that place and checked by the computation of flow through the sluice gates of the Merrill Electric Light and Railway Company's dam, was equal to 25,300 cu. ft. per second for a few hours. The flow at Tomahawk, computed from the gate openings and wheel capacity at the Tomahawk Paper Mill, was about 7,900 cu. ft. per second. The increase in flood flow was therefore about 17,400 cu. ft. per second, for the 700 square miles between Tomahawk and Merrill, or a rate of about 24.8 cu. ft. per second per square mile. Plate III shows the results of various measurements and computations of flood flow through sluice gates of dams, together with details of the rainfall as complete as possible.

The rainfall that caused the flood flow of 24.8 cu. ft. per second per square mile between Tomahawk and Merrill was about

2.90 in.	in 2 days,
4.35 in.	in 4 days,
6.03 in.	in 10 days,
10.00 in.	in 30 days,

and a rainfall departure from the first of the year to August 31st of +3.34 in.

Careful investigation at Merrill in June, 1912, showed that this probably was the most severe flood that had occurred in the past 20 or 30 years.

The excess of rainfall from the first of the year, of 3.34 in., together with 10 in. of rainfall in the 30-day period, were such as to make extreme flood conditions possible. Should the culminating rain in the 2-day period have been equal to 6 in. in place of 3 in., the rainfall condition as to amounts of rainfall, in 2, 4, 10, and 30 day periods would have been practically the same as at Monmouth, Illinois, for 2,500 square miles. It seems certain that such rainfall conditions would have produced a flood flow from the 700 square miles between Tomahawk and Merrill of at least 30 cu. ft. per second per square mile. As heavier rainfalls may occur on 700 square miles than on 2500 square miles, as shown by curves Nos. 2 and 3 on Plate I, it is probable that at some time, perhaps only once in 50 years, the flood flow for this district of 700 square

miles may be equal to from 35-40 cu. ft. per second per square mile.

The extraordinary rainfall of July 23rd and 24th, 1912, amounting to 11.25 in. in 24 hours, occurred subsequent to this investigation, and such data as are available at the present time indicate that a flood flow of from 40 to 50 cu. ft. per second per square mile occurred from the 700 square miles of drainage area between Tomahawk and Merrill.

Measurement of flood flow of the Spirit River, at Spirit Falls Dam, and of the Prairie River at the Paper Mill in Merrill, is outlined in Plate III, and showed flood flow values of 27.5 and 16.5 cu. ft. per second per square mile respectively.

On the Wisconsin River above Tomahawk, and especially above Rhinelander, the conditions of the drainage area are somewhat different. The gradual slopes to the river are more broken up with inland lakes, depressions, and valleys. The smaller lakes and depressions are frequently without outlets except through seepage. It is probable that about 25% of the drainage area above Rhinelander is such that the run-off must be through ground water flow or seepage.

Existing flood flow data are not very reliable, but indicate that values of from 8-10 cu. ft. per second per square mile have occurred. The North Pelican River gave an average of 5.0 cu. ft. per second per square mile for 15 days (Plate III) from 89 square miles. The measurement was of the flow from the lake having $1\frac{1}{2}$ square miles of water surface. The indications are that the maximum inflow to the lake was at a rate of about 10 cu. ft. per second for not exceeding 2 or 3 hours. This stream rises in large swamps and is a remarkably steady stream.

The rainfall that produced the flood flow was 2.48 in. in 2 days, 3.56 in. in 4 days, 4.66 in. in 10 days, and 6.98 in. in 30 days. With the heavier rainfall conditions that may occur for a drainage area of 89 square miles, there is little doubt but 20 or even 30 cu. ft. per second would result.

After considering all of the circumstances of inland lakes and depressions and other characteristics of the watershed from personal observation, together with such flood flow data as are available for moderate rains that have occurred, and making comparison with the available flood flow data from the district between Tomahawk and Merrill, and other rivers personally known to the writer, the judgment of the writer is, that for drainage areas of about 400 square miles, along the main Wisconsin River above Tomahawk, rainfalls are liable to occur at least once in 50 years which will produce a flood flow of 20 cu. ft. per second per square mile under present agricultural conditions. To allow for improved conditions of agriculture, the value is increased 50%, making 30 cu. ft. per second per square mile as representing the extreme flood flow that would occur about once in 50 years. Plate II, curve No. 2,

shows the flood flow in cubic feet per second per square mile that may be anticipated for other drainage areas.

The curve is intended primarily to represent rare floods along the main line of the Wisconsin River above Tomahawk, but may also be taken as representing rare floods as far down stream as Merrill. The curve does not apply to branch streams, except such as have flat slopes and are typical of the general topographical conditions of the district above Tomahawk. Branch streams like the Prairie and Spirit Rivers between Tomahawk and Merrill have quite steep longitudinal and transverse slopes, and would have larger flood flow units than shown by the curve.

The writer desires to thank the managers of the various water power plants, and Mr. A. A. Babcock, manager of the Wisconsin Valley Improvement Co., for their valuable assistance in securing data concerning this investigation.

THE DESIRABILITY OF REVISING THE RATING AND METHODS OF TESTING ELECTRICAL APPARATUS

BENJAMIN G. LAMME,* MEM. A. I. E. E.

*Presented at a joint meeting of the Electrical Section, W. S. E., and
Chicago Section, A. I. E. E., January 27, 1913.*

The subject which has been put up to me is that of the desirability of revision of the rules of the American Institute of Electrical Engineers, including the methods of rating. It is a broad subject, and I cannot expect to cover more than a small part of it, in the time allowed me.

In the first place, I will give a little of the history of the Institute rules. These rules were prepared a good many years ago by a committee appointed by the Institute, and about every three or four years since they have been revised and temporarily brought up to date. An unfortunate feature is that they have always followed far behind actual practice and never have led or indicated what good practice should be in the future. As they were never ahead of the times but always far behind, they have not been followed very closely by the electrical public.

Some three years ago, the Standardization Committee of the Institute named a sub-committee on ratings. The object of the sub-committee was to formulate some more consistent system of rating apparatus than the present one. This sub-committee worked about a year, with practically no result, because they could not find any entirely satisfactory or consistent method for the rating of apparatus. That committee was continued into the following year. The next year the Standardization Committee of the Institute named a second sub-committee to undertake a general revision of the standardization rules. Dr. Steinmetz and myself were named for the second committee. The sub-committee on ratings was made up of three representatives of large manufacturing companies, it being the idea, apparently, that the manufacturing companies' representatives would have at hand much data of all kinds upon which to base satisfactory methods of ratings.

The two committees on methods of rating and revision of rules have both followed similar lines, and have been working together very closely.

One of the first points brought out in regard to revision was that the rules heretofore had always been much behind the times. In trying to formulate existing practice, they necessarily could not quite keep up with the latest practice. By the time the rules were ready to be issued by the Institute they were probably a year or two behind the times. One of the first suggestions in connection with the revision was that possibly in preparing new rules they could be

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so up-to-date that they might even indicate the present tendencies, or could, to some extent, anticipate the changes which are now taking place. We know that certain things are coming into practice;—we can clearly foresee them. As one example, take the method of rating of alternating current generators. It has been the past practice to rate such generators in kilowatts at 100% power factor. We all know that we must eventually adopt the kilovolt ampere rating at some specified power factor lower than 100%. Therefore, why not recommend the kilovolt ampere rating as the standard and thus anticipate and direct the coming practice: The same holds true of many other things.

In going over this matter, it was evident that a great many changes which have occurred in the last few years could have been foreseen to a certain extent, and could have been formulated into rules, which would have assisted greatly in fixing practice.

When such suggestion was made in regard to this possible course of procedure by the Revision Committee, the committee on ratings immediately accepted it as a partial solution of the difficulties in formulating a method of rating. The committee members decided that possibly they could foresee coming practice in making new rules for rating, which would possibly apply five or even ten years from now, as well as in the immediate future.

The first work of the two committees was to study the deficiencies of the old rules of rating and standardization and look over present tendencies. It was evident that there are a great many defects in our present rules, and it was apparent that we would have to change them in a number of very important points. We soon found that we could propose some important improvements over the old rules, but some of these changes were so radical that it was decided to present them to the public before attempting to put them in the rules. Heretofore it has been the custom for a few members to decide upon what is good or standard practice, and then include these changes in the rules and let the public pass upon them afterwards. But after the long delay in preparation, the public would not accept them, partly because they were out of date. But this time we are going to present these changes to the public before they are incorporated in the form of rules, and if they are acceptable, they will afterwards be adopted by the Standardization Committee.

In this standardization work, it was considered that there should be no standardization in design, because any standardization in real design is going to suppress improvement; but the standardization should apply to methods, practices, etc. Particularly, the rules should be so plain that there will be definite meanings to contracts and guarantees. For instance, a contract, as now taken, calls for certain guarantee tests, etc. Those tests may mean one thing to one manufacturer, another thing to another manufacturer, and still something else to a third manufacturer. The methods of

testing are different in different companies, and they thus obtain different results. A rating does not mean the same to two different companies, and it does not have the same meaning to different purchasers of such apparatus. Therefore, it is very necessary that methods of rating, testing, etc., shall be so exactly and correctly defined that they will have the same meaning to everybody, and that is wherein the proposed new standardization is going to be valuable.

In order to present to the public this proposed standardization, with the new methods of rating, etc., it was decided to hold a standardization convention in New York City the latter part of February, at which there will be forty or more papers presented on various subjects, in connection with the problems of ratings, temperature, methods of testing, etc., most of which are of very great interest to both users and manufacturers of electrical apparatus. The papers received are unfortunately mostly from engineers of manufacturing companies. We would like to have received more papers from other branches of the industry. These papers will be printed in the February issue of the Proceedings of the Institute, and the Standardization Committee will be very glad to have any constructive criticisms in line with them. Of course, destructive criticism is all right if one puts forth something better in place of what he tears down, but we do not desire mere fault finding. We want something that will be helpful in making the new rules, and we want to build up the new rules on the experience of all those interested in the matter. We would also like to have the opinions of as many people as possible on the various subjects, as we desire the new rules to be in accordance with public opinion, if possible.

What I expect to do tonight is to go over some of the ground the committees have covered, state some of the deficiencies of the old rules, and indicate in a general way some of the lines along which we are working.

Among the convention papers are two prepared by the two sub-committees,—one on the general subject of rating, in which a new method of rating machinery is proposed, and the other on the general subject of temperature and insulation, prepared by the sub-committee on revision. These two subjects are really the most important to be dealt with in the proposed standardization, and therefore they were made the subject of committee papers. The paper on temperature and insulation is very radical, but it is the result of over a year of hard work on the part of two committee members and their engineering associates. The subject of temperature is really back of so many other points that it might be considered the basic subject of the whole convention. The whole subject of temperature guarantees at the present time is based upon a misconception. Everything is based upon *temperature rise*. But *temperature rise*, in itself, has no meaning. The *temperature rise* does not hurt apparatus. It is the *ultimate temperature* attained that

injures apparatus. We have gotten so far away from the original reasons for specifying temperature rise, that people have come to think that the rise itself is the important feature. That is where the new rules are going to depart from the old ones. It is proposed to make ultimate temperature the basis of measurement, for this is surely what we are going to adopt at some time in the future, and so we might as well anticipate it.

For some time many engineers have appreciated the fact that temperature rise without other determining conditions is a wrong method of specifying the temperature limitations of electrical apparatus. They have recognized that the ultimate or absolute temperature is the real or danger limit, but it has been hard to break away from such a well-established practice as the present one. One way to do this is to have a body like the American Institute of Electrical Engineers take up the subject and recommend a better method. This would be looked upon as an unbiased or impartial method of changing from the present practice, and if the new rules of the Institute cover a more correct method of specifying temperatures, it will be adopted eventually by the public.

As stated before, it is the absolute temperature attained which is liable to damage insulation. The rise is only incidental to the measurement of the absolute temperature, as I will refer to later. This subject has been covered very thoroughly in the sub-committee paper on temperature and electrical insulation, which is now in print, and advance copies of which can be obtained by anyone who wants to send for them. This is a paper which should be analyzed and discussed very thoroughly.

I will go over a little of the ground covered by this paper. I do not want to anticipate the paper in full, but I will select a few of its points.

In this paper on temperature and electrical insulation, we bring out clearly that insulating materials should be considered from two distinct standpoints; namely, the mechanical and the electrical. It is a fact which is not generally appreciated that the harmful effects of high temperature on insulation are largely mechanical. That is, insulation will stand more from the electrical standpoint when overheated than it will from the mechanical. The fact is that ordinary insulation, when it is overheated, gets brittle, or semi-carbonizes, or flakes off, or powders, and thus becomes mechanically unfitted for its purpose. With ordinary voltages, the thickness of the insulation used is generally such that it acts more as a mechanical separator than as an insulator. That is, the distance between two conductors ordinarily obtained by putting insulation between them, is more than sufficient to stand the voltage if that amount of separation had been obtained without intervening insulation; that is, the air distance alone is sufficient. The real function of the insulation is not as a dielectric as much as it is to keep the conductors mechanically apart, and to keep out foreign substances which might be conducting. The principal result of overheating

insulation is that it becomes faulty from a mechanical standpoint and may disintegrate and allow the conductors to touch each other or some other conducting part. Insulation can be heated up until it is practically carbonized and may still be very good insulation, from the dielectric standpoint, while mechanically it would be worthless.

As an example, I will cite one case of trouble in a high voltage machine where a breakdown between two conductors followed a terrific short circuit across the terminal. This machine, some time previously, had carried a tremendous overload. We found that the insulation between turns in each coil was much like charcoal, but the binding material was such that it did not crumble or powder. The customer said he must have the machine quickly, and wanted to know if we could apply a test to see if the insulation was reasonably safe. So we separated the ends of each coil and applied about twenty times the voltage between turns and did not find one defective coil, thus indicating that they were mechanically separated, even if the insulating material was in bad condition. The machine was put in service, with the idea of re-insulating it at some future time. That is nearly four years ago, and the machine has been in regular service, with the insulation carbonized, yet there has been no trouble. But the machine is in such bad shape that a severe shock might cause the insulation to crumble and cause a short circuit. Electrically, the insulation is all right, but mechanically it is very bad.

The durability of the insulating material is a function of the temperature, but there is no such thing as a definite life of insulation. For instance, at one temperature an insulation will stand possibly ten years without undue deterioration from the mechanical standpoint, and electrically it may be perfectly good. At a somewhat higher temperature, it may stand two years only. For instance, let us assume that the insulation is subjected continuously to 100 deg. C. actual temperature (not thermometer measurement). Under such a temperature, good fibrous material may last indefinitely, or ten years or more. But at 110 deg. C. the same insulation may, in two years, reach a condition where it is mechanically unsafe. At 125 deg. C. it may last three months, and at 150 deg. C. it may last a few days, while at 200 deg. C. it may last for a few hours. It is therefore impossible to fix any definite figure for the life of insulation. It depends upon the quality of the insulation, as well as a great many other things, but we know certainly that, in many cases, insulations have actually operated at higher temperatures than we suspected, because our methods of determining the highest ultimate temperatures have been defective. It has been quite thoroughly believed that fibrous insulations will stand 90 deg. C., for it is known that machines that measured up to 90 deg. C. have operated with but little deterioration, except that the insulation got dry and brittle. But we now know that

somewhere inside that insulation it has been somewhat hotter than our measurements showed,—possibly 10 degrees or more. Therefore, in the light of the latest and best information obtainable, the usual fibrous types of insulation will actually stand 100 deg. C. ultimate temperature for a long period, perhaps ten years or so, without undue deterioration. It is also known that such an insulation will also stand 110 deg. for quite long periods, but the life is very appreciably shortened. It is obvious that if we knew the approximate length of life of any given insulation with any given temperature we would have some very useful data for guarantees, etc. But as yet we have not obtained thoroughly reliable specific data, and we have had to base our recommendations on general data. We collected all the data we could find and plotted the results in a curve which gave the approximate life of insulation in terms of temperature. The plotted results indicated that 100 deg. C. can be taken as the highest temperature which can be allowed with good types of treated fibrous type of insulation, with expectation of a reasonably long life. Higher temperatures than that appear to appreciably shorten the life.

Another thing that appears to be true is, assuming that the insulation can stand 110 deg. C. ultimate temperature for possibly one year, if continuously applied, it can stand the same temperature for an equal period if applied intermittently. That is, if we apply it only one-tenth of the time, the total life of the machine in years would be ten times longer than if applied continuously, provided, during the intermediate periods, the temperature was below the danger point, or below 100 deg. C. That is a very important condition in certain kinds of operation. For instance, if you have a piece of apparatus which carries a very intermittent load, or has to carry a peak load at very infrequent intervals and the rest of the time carries little or no load, there is no reason for putting a temperature limit of 100 deg. C. on such a machine, because it could be operated up to 125 deg. C., or even 150 deg. C., and the total operation over a period of years might represent only a few days of total operation at the high temperature. I am taking that as an extreme case, but in practice no machine with fibrous insulation would be guaranteed for 150 deg. C.

In considering ultimate temperatures, we have no direct method of measuring such temperatures. If we are to base ratings on ultimate temperature, and not on temperature rise, we should have some means for approximating the real temperature. The temperature of the hottest part may be considered made up of three elements. First, the temperature of the cooling air or medium,—that is, the air that actually cools the apparatus. Second, the rise in temperature above that cooling medium, which is a temperature we can very often measure. The resultant of these two is the ultimate *measurable* temperature, not the true ultimate temperature. Beyond that, we have a still hotter part due to the temperature

drop through the insulation, which is difficult to determine, but which can be roughly approximated.

We may measure the temperature of the ingoing air and obtain, say, 25 deg. C. We then may measure the increase in resistance of the winding and get 50 deg. C. rise above the cooling air. That gives us 75 deg. C. measured temperature, but not the true inside temperature. We know when we determine the increase in resistance of a winding that we do not get the resistance increase of the hottest part, but only an average value. We know that there is liable to be some difference in temperature between various parts of the winding. In many cases, we know that the hottest part is possibly 5 or 10 degrees hotter than the average. That has been determined by calculation and by elaborate tests. But if we know that the internal temperature drop will be about 10 deg. C. then we can add this to the measurable temperature, and get a fair approximation to the ultimate temperature, and that should be the real measure of what the insulation will stand. Temperature rise is only one of the elements in this result.

Again, if we measure temperature by the thermometer, we know it is only in rare cases, in windings, that we can place the thermometer directly on the copper. There is always a drop in temperature between the copper inside the insulation to the thermometer outside. This drop cannot easily be determined except by laboratory experiments, or by calculation. With the ordinary low voltage machines, that drop may amount to 5 deg. C. or 10 deg. C., but on high voltage windings, with very heavy insulation, it may be 20 deg. C. to 30 deg. C. It is evident, therefore, that if you measure the temperature on the outside and do not allow for the internal drop, you might be badly misled, and might get very high actual temperatures in high voltage machines. For that reason, such machines have to be considered differently from the ordinary low voltage machines.

We have designated the temperatures obtained in the usual manner by the use of a thermometer or by resistance rise as *conventional temperatures*, and these methods as the *conventional methods* of measuring temperature. That is, we say a machine is to have a certain rise by conventional methods of measurement. If 100 deg. C. is all the insulation can stand, and we allow a 10 deg. drop for internal temperatures, then that gives us 90 deg. C. as the maximum permissible temperature by conventional methods. Please keep in mind that the conventional is always somewhat lower than the actual.

As the ultimate temperature attained depends upon the actual temperature of the cooling air, we must take this into account in specifying any ratings based upon ultimate temperatures. The average machine will operate in a temperature of about 25 deg. C., taken all over the country, and at all times of the year, but, in some cases, a machine must be operated in air temperatures as high

as 40 deg. C., or higher in exceptional cases. But the manufacturer must take into account that machines of a certain size or type may be installed under all kinds of conditions where the temperature may be 40 deg. C. or only 10 deg. C. He must therefore recognize an upper limit. Taking 40 deg. as this limit, and 90 deg. C. as the ultimate limit by conventional measurement, that means that we have a permissible rise of 50 deg. C. Adopting this as the permissible rise, then with air at 40 deg. C., and with 10 deg. C. internal drop, a maximum temperature of 100 deg. C. is obtained, which is all the machine will stand. But if that machine is operated in air at 25 deg. C. then with the 50 deg. C. permissible rise it will measure 75 deg. C. by conventional methods, and will have about 85 deg. C. inside. Under this condition of air temperature the machine has a margin. That puts a premium on methods of cooling the machine, which is to the customer's advantage in overloading. The manufacturer, under the proposed method, is not allowed to take advantage of that fact, because the same size or type of machine may be installed at 40 deg. C. and in consequence will run above the guarantee if overloaded. It is therefore proposed to fix an upper air temperature of 40 deg. C. and a standard rise of 50 deg. for all air temperatures of 40 deg. C. or less, and allow 10 deg. internal drop for moderate voltage apparatus. For high voltage coils, with heavy insulation, the internal drop may be 20 deg. to 30 deg., and in such cases 90 deg. C. by measurement will not be allowable with fibrous insulations.

It should be noted that in taking temperatures by thermometer we obtain the ultimate temperature at once, without considering the air temperature. In such case, it is only necessary to determine the cooling air temperature to find whether the guaranteed 40 deg. C. upper limit is exceeded.

It is obvious that, on this basis of rating, the temperature of the cooling air should be taken, and not simply the surrounding air. In our present practice we refer to the temperature of the surrounding air. But the temperature of the surrounding air is not what we are after,—it is that which acts to cool the machine. We are after the ultimate temperature, and one of its elements is the temperature of the ingoing or cooling air. Therefore, we should measure that as closely as we can. If a machine is placed in a pit or where the bedplate of the machine forms a badly ventilated pit, then the air in the pit will be heated, and the machine as a whole will be heated somewhat by the hotter air from the pit. If the air that is blown out of a machine is deflected right back into the machine, then the temperature of this warmer ingoing air should be taken into account. Anything that affects the temperature of the machine should be taken into account. We do not care to measure the temperature of air which does not go into the machine, or of parts of the room which have nothing to do with the machine. I have seen machines, running in room air at 20 deg. C., show an

abnormal ultimate temperature; but upon measuring the temperature of the air going into the machine, it was found to be 50 deg. C. The difficulty was in the way the air was fed into that machine. No matter who was to blame, that was the real defect, and the remedy was to deflect the outgoing air so that it did not go directly into the machine again, and that was rather easily accomplished. This particular test illustrates the fallacy of the present method of temperature guarantee. We were attempting to keep down the temperature rise, and not the ultimate temperature. If that machine had shown only 40 deg. rise over the surrounding air, it would have been considered satisfactory by the Institute rules, although, with the actual cooling air at 50 deg. C. the ultimate measured temperature would have been 90 deg. C., and the internal drop probably 20 deg. C. to 25 deg. C., as it was a very high voltage machine. This would have brought the actual temperature up to 110 deg. C. or 115 deg. C. at normal load, and much higher at overloads. Nevertheless, by the Institute rules, that machine would have been considered acceptable, though we now know it would not have been satisfactory.

I have referred repeatedly to the internal temperature drop or gradient. In some cases the measurement of temperature can be such as to eliminate the internal temperature gradient. Take, for instance, those windings which are completely immersed in a cooling fluid, such as oil, or are enclosed in such a way that they have equal temperature throughout. In such cases, the average and the maximum temperatures will be equal, and the determination by resistance increase will give the true temperature of the hottest part. Obviously, in such cases the ultimate temperature attained will be the cooling medium plus the temperature rise, with no internal drop allowed. In all other cases we may have difficulties in getting at the actual ultimate temperature, but in the proposed new rules we are working toward a definite result. The difficulty is going to be to decide upon the internal gradient or drop. With ordinary low-voltage windings it is not so difficult to approximate the actual temperature, either by the thermometer or by the resistance, because the temperature drop from the inside to the outside, or from the hottest part to the average, is only a few degrees. Furthermore, I think that the tendency of design is toward more uniform temperatures, wherever possible. That is, we are trying, at the present time, to so proportion the apparatus as to get as uniform a temperature as possible over the various parts, because that represents economy in design. It does not pay to have insulation very hot in one place and very cold in another; what we are aiming to do is to cool the hot parts. I think the new rules are going to lead toward greater uniformity in temperature. Heretofore, as we have guaranteed temperature *rise*, the aim has been to get the temperature of those parts which were measured as low

as possible, as it was temperature rise we were after, and not the temperature at the hottest part.

The problem of internal temperature in windings is a very complex one. Take, for instance, an armature coil;— the heat generated in the coil partly flows directly through the insulation into the core and from the core into the air, so that there is a certain temperature drop from the inside of the copper through the insulation to the core and to the air. But part of the heat will also flow lengthwise of the copper to the end windings, and then through the insulation to the air. There might be, through one path, 5 deg. drop from the copper to the iron, and possibly 40 deg. drop to the air, making 45 deg. total drop from the copper to the air. There might be, along the other path, 5 deg. drop from the center of the core to the end winding, and 5 deg. drop through the insulation, and 35 deg. from the insulation to the air, making 45 deg. total. In some cases, nearly all the copper heat may be dissipated through the end windings, while in other cases, the end windings, if not well ventilated, may be hotter than the core, and heat may be conducted from the ends into the core. As the armature copper loss varies as the square of the load, while the iron loss may remain fairly constant, then at light load the heat flow may be from the core to the copper and out at the end windings, while at heavy load the flow may be reversed in direction. In many cases a few degrees difference in temperature between different parts of the coil will cause a relatively large transfer of heat from one part to the other. In the ordinary types of machines with narrow cores, there is liable to be a fair equalization of heat throughout the whole coil. It is only in machines with excessively long windings that large differences in temperature are liable to be found. Such are found in large high speed machines, where conditions of speed force the designer to use very wide armature cores, and therefore great coil lengths. In such cases, where a thermometer on the end winding, or a resistance measurement, may be far from indicating the highest temperature, even after allowing for a relatively large internal drop, other means for indicating the temperature are coming into use. The two most common methods are exploring coils and thermo-couples. These are placed in the slots, near the center of the core, or wherever the temperature is liable to be highest. By such means, we obtain an approximation to the temperature of the hottest part. To this should be added an approximate internal drop, depending upon the thickness of the insulation, and various other conditions. In such machines you may get a rise of 10 deg., 20 deg., or may be 30 deg. C. from the copper to the core. In machines of this type, where we may have a high drop from the copper to the core, and the center of the core is possibly much hotter than the outside parts, the ultimate temperature attained may be so high that we cannot use ordinary fibrous insulations. Suppose the core temperature rises 40 deg. C. at the center: if the

copper inside the insulation at the center rises 30 deg. C. above the iron, we then have 70 deg. C. rise to begin with at the central part of the copper. Now if we have air at 40 deg. C., which is likely to be the case in some instances, we will get, to begin with, 110 deg. C. inside the coil, which is obviously too hot for fibrous insulation. Now, if we bring that down to 100 deg. C. and allow ourselves a little margin, we must build a machine that the temperature rises only 20 deg. or 25 deg. C. in the core, and may be only 20 deg. or 25 deg. C. in the end winding. We would be working the larger part of our material at an absurdly low condition, simply to accommodate one small part of the winding where we cannot get the heat out. This condition has led to the use of mica on the buried parts of the coils of high voltage machines with long cores, and experience has shown that such insulation will stand 125 deg. C. just about as well as fibrous insulation will stand 90 deg. C. It is proposed in the new rules that such insulation be allowed an ultimate temperature of 125 deg. C. by conventional measurements, such as thermometer, resistance, or thermo-couples, instead of 90 deg. C.

Obviously, in the wide core, high voltage machines the temperature of the end winding does not mean anything unless much additional data are obtained at the same time to show the true internal drops. With exploring coils in the slots to determine the temperature, we not infrequently get 70 deg. C. or 80 deg. C., whereas the ordinary methods of measurement may show only 40 deg. or 50 deg. C. So, if the exploring coil methods of measurement are adopted in the future, they will probably carry higher temperature guarantees. That is, the measurements, instead of showing 50 deg. C., may indicate 70 to 80 deg. C., but it will be understood that these higher readings represent very nearly the hottest part of the machine, whereas the older methods did not.

I will now compare the present rules on ratings and temperatures with the new or proposed rules. You will find that the present Institute rules and the present method of rating machines allow 40 deg. C. rise by measurement of temperature with thermometer, or 50 deg. C. by increase in resistance. Nothing is said about the ultimate temperature attained, or the highest permissible temperature of the cooling air: 40 deg. by thermometer is considered the same as 50 deg. by resistance. But with air at 40 deg. C., and 50 deg. C. rise allowed, we get 90 deg. C. by measurement, and if we allow 10 deg. internal drop, we get 100 deg. C. normal rating. In addition to that there is an allowance of 15 deg. rise for overloads, and allowing for an increase in the internal drop due to the overload, we will have 116 to 117 deg. C. permitted under the present rules. We know that is not a safe guarantee, and the proposed rules do not allow it; yet it has been claimed by some that this proposed new method will work our machines harder than before. But if you get down to actual figures, you will find that it is actu-

ally safer than the former guarantee, as 100 deg. C. is the limit, while there is no true limit under the present rules. The reason we have not had any particular trouble in the past with the present rules is because machines have not been run in 40 deg. C. air to any considerable extent, and many machines have not been closely fitted to their service. But at the present time, conditions of application are becoming so well known that we are coming closer and closer to the limit, and eventually our present methods of guaranteeing and rating are liable to get us into trouble if we continue them. The new rules will avoid that difficulty.

If an ultimate temperature limit of 100 deg. C. is allowed, and a given machine will operate continuously at 100 deg. on the hottest part, then that fixes the capacity of the machine, and that should be the basic or reference point in the application of the machine. As a reference rating, we have selected that as the "basic" or "single" rating. This must not be confused with the present "normal" or "full load" rating. The single rating fixes a limiting condition in terms of temperature. You can take a machine on such a rating and apply it, with any margin you desire in your application of it. You fix the overload to suit yourself, using the single rating as a limiting condition.

There are a good many absurdities in our present methods of rating, and one of them has been coming up lately with some frequency. It is the question of extreme overloads under the present method of rating. For instance, a machine will be sold for a certain normal rating, and on top of that will be a tremendous overload for, say, two or three hours. I have known many machines to be sold for a certain normal rating with a 50% overload for three hours, with a certain temperature rise. There seems to be an idea that one is getting something extra by that method of rating. But the fact is that the designer must design for the peak condition of three hours overload, and the normal rating doesn't control the design at all. The machines will probably reach a steady temperature on the three hours of overload. The overload is therefore practically a continuous rating. For instance, a machine is specified as 1500 kw. with a two-hour overload of 100%. That means 3000 kw. for two hours. That particular machine may reach within five degrees of its steady temperature at the end of two hours. The designer does not lay out a 1500 kw. machine for a specified low temperature of 30 or 35 deg. C., with the expectation that it will therefore carry large overloads, but he actually designs for the 3000 kw. rating, and expects it to carry, easily, the normal load of 1500 kw., or anything else below 3000 kw. He actually builds a machine that will carry 3000 kw. and yet, on account of the 100% overload specified, he derates it to 1500 kw. That is, he builds a machine for 3000 kw. in order to give 100% overload. That is what existing practice leads to. We sell many machines in that way because people so specify, but there is no good reason

for it. If a machine will actually carry 3000 kw. without exceeding safe ultimate temperature, why not rate it by what it is actually capable of doing continuously. Why call it 1500 kw. when this is a purely arbitrary rating, depending upon some arbitrary percentage of overload? Different overloads are called for by different purchasers, and this leads to great confusion at present. By fixing a basic or single rating, for any given machine, then anyone can apply the machine to suit his special load conditions, on the basis that his most severe conditions do not exceed the single or basic rating of the machine.

When you come to peak rating, or the capacity for a momentary period, that is a different thing. It does not affect the temperature to any extent. A machine that reaches 100 deg. C. ultimate temperature in one or two hours may carry a high peak load for a minute or so without distress and this load might even be 200% or 300%, depending upon the duration of the peak. It is only when the element of time comes in appreciably that a temperature limit need be specified. Therefore, in the proposed method of rating, momentary or peak overloads are to be allowed.

To show the fallacy of some of the present methods of rating, we have made estimates for alternators of large capacity where the purchaser specified, under one condition of loading, a rise of 30 deg. C. in both iron and copper; and under another condition of loading, 40 deg. C. is called for continuously, while under a third condition of loading, 50 deg. C. is specified. Now if, under any condition, 50 deg. C. is allowed, what is the necessity for specifying 30 deg. C. rise in another condition? If 50 deg. C. is safe, is not anything below it safe? But such a specification shows clearly a further weakness in our present method. Both iron and copper are given the above 30 deg., 40 deg. and 50 deg. rises, under the different conditions. But the iron loss is much more constant than the copper loss for different loads on a given machine. If the machine is designed for 30 deg. C. in the iron in one case, it will not reach 50 deg. in the other case, where 50 deg. is allowed. On the other hand, if designed for 50 deg. C. under the higher load, it will not be as low as 30 deg. for the lower load. Therefore, the two limits are inconsistent, as far as the iron is concerned, if they are consistent as regards copper temperatures. To meet the 30 deg. iron temperature meant a much larger core than necessary for the 50 deg. condition. Therefore, this rating meant an unduly large and expensive machine, as far as the iron is concerned, and yet it is not the iron loss which is a controlling feature in determining the ultimate temperature of the insulation in this case. In measuring the iron temperatures, you can actually put your thermometer or exploring coils directly on the iron, and obtain the true temperature attained, which is not the case when measuring the copper temperatures; yet the specifications are so worded that, on the heavy load conditions, the copper will reach

ultimate temperatures far above the iron. For economy, the copper and iron temperatures under the heavy load conditions should be more nearly equal, but the low iron temperatures called for at normal or lighter loads preclude this equality at the heavier loads. What we ought to do, for best results, is to work the iron a little harder and the copper a little easier. Then we would have a machine which is more consistent throughout. Such a machine would not show as low iron temperatures at light load, as on present machines, but would be a better machine for the heavy service, and the cost would not be materially different from what it is at present; but it would represent a more balanced design than the present forms of guarantee will permit.

I have covered principally the subject of temperature and ratings. But there are other subjects to be treated in the convention. One of these is the measurement of losses and the determination of efficiency. That has been a very troublesome question in the past, because opinions and methods have differed so much. There are two methods specified in the present rules for determining efficiency. One is by separate measurement of the losses, and the other is by input-output measurement. It looks, on the face of it, as if the measurement of input and output is the ideal scheme, but when we come to carry it out practically, it does not so work out, as the combination of many very small errors in the method will generally sum up to 1% or 2% total error in the result. You may consider the losses in a machine as consisting of certain measurable losses, such as the iron and copper losses and the friction and windage, and certain other non-measurable losses, which we may call "stray" losses, or "load" losses, or "extra" losses. These consist principally of eddy losses in the copper and iron loss due to flux distortion. In practically all cases, these stray losses are a comparatively small element compared with the other losses. The other losses can be measured very exactly, but the stray losses are very difficult to determine. If we could add to the measurable losses some small factor which is only a reasonably close approximation to the stray losses, we would still have a good approximation to the true efficiency, for the stray loss being so small, a slight error in this part would not affect the result appreciably. This is called the separate-loss method of determining efficiency. In this we measure the major losses accurately, and have to approximate roughly certain minor losses. But in the input-output method, we measure the total power input and output separately, and only a small part of this represents loss. An error of 1% in the input or output measurement may represent 10% to 20% of the total losses, and is liable to represent as great an error as if the stray losses were altogether neglected in the separate-loss method. But as two sets of readings, input and output, have to be taken, an error of 1% can usually be expected, except under laboratory conditions of testing. As one engineer expressed it, the measurement of efficiency by input-output is like

measuring the thickness of a sheet of paper with a 1-foot rule. One might get the right result, but a sensible person would not have any great confidence in it. The merit of the separate-loss method of measurement is that we actually measure certain principal losses, such as iron and copper losses, windage, etc. Sometimes it is quite an advantage to know the separate values of these, but the input-output method at best can show only the sum of the losses.

The results obtained up to this time, indicate that the extra losses are very small in some kinds of apparatus, such as synchronous converters, the usual types of induction motors and transformers. But in A. C. generators of the polyphase type, the stray losses are appreciable, probably representing $\frac{1}{2}\%$ to 1% of the output of the machine. In D. C. generators they may average slightly higher than in A. C. machines, as commutation losses are included as part of the extra losses. Now, if we assume $\frac{1}{2}\%$ extra loss for A. C. generators and synchronous motors, and 1% extra for D. C. machines, our average error would probably not be as large as $\frac{1}{2}\%$, which is a much closer approximation than can be obtained in the determination of efficiency of all kinds of apparatus in general, and is practically much closer than could be obtained on the average with electrical machinery by input-output methods.

The general conclusion reached is that the separate-loss measurement of efficiency is a more reliable one than the input-output, and at the same time, it is much easier to carry out than the latter. The input-output method is very expensive. A test of this sort, if carefully made, will cost several hundred dollars. Now, that has to be paid for in some way. If the order for the one set does not cover the cost, then it must be distributed over the costs in general, and the public pays for it in the end. But the method is not worth this expense, as it is not accurate, and it therefore puts an undue burden on the industry.

We will consider, next, the problem of methods of loading machines, especially those which are so large that it is impracticable to put on actual dead load. In some cases, several equivalent load methods have been proposed, each having certain merits, but none are quite correct, for each requires some minor correction in the results obtained. The convention papers will describe a number of these methods, and explain the errors in each method. Certain of these methods will probably be recommended in the new Institute rules.

One of the difficulties now is that a certain guarantee is made, and when we come to carry it out, the purchaser and the manufacturer's engineers cannot agree as to what is a proper method of testing. But if certain methods were recommended in the rules, and were specified in contracts, the present difficulties would largely disappear.

In closing, I would say again that it has been impossible to cover the whole list of convention subjects. I feel that I could have made

a more consistent presentation if I had had more time. If you will study the two committee papers now issued, they will give you a much more complete presentation than I have been able to give this evening. The other papers, to appear in the February Proceedings of the Institute, will cover the various subjects that I have mentioned, such as loading, measurement of losses, etc.

DISCUSSION.

Wm. B. Jackson, M. W. S. E.: I believe that I voice the feeling of us all, in expressing the great pleasure and profit I have had in listening to Mr. Lamme's discussion of this vital subject. I feel that we are to be congratulated in having been, in a way, taken into Mr. Lamme's confidence. As you probably know, there is no one in this country or abroad who can speak with greater authority on this subject than Mr. Lamme. We should appreciate that, in the work certain men of the American Institute of Electrical Engineers are doing for the electrical profession, in working out these standards, the chief aim is not merely to give us standards in accordance with which electrical apparatus may be built, and in accordance with which it may be tested, but the desire is to have standards for the performance and testing of apparatus which will prompt the construction of apparatus in which the most economical use of the materials involved in its construction will be made. By thus encouraging the construction of apparatus most suitable for its purpose, at the least possible cost, those interested in the purchase and operation of the apparatus will be directly benefited.

Some here are not members of the Institute, but we are all vitally interested in this matter of having the best possible electrical apparatus. It is my hope that when the Institute finally produces a set of standards that will fulfill the requirements of the present, as well as, according to Mr. Lamme's prediction, for a considerable period in the future, the Western Society of Engineers, and other important engineering societies, will not only accept them, but will formally adopt the standardization rules for application as the official procedure in cases where electrical tests are made by members of the Society.

Hugh Paterson (Smoke Abatement and Electrification Committee): I have listened to Mr. Lamme's paper with a great deal of interest, and I have learned from it, as I think we all have, many things that will give us food for thought.

I have no particular comments to offer, but I feel that we should do as Mr. Jackson has said, encourage the following up of the rules, and those who have constructive criticisms to offer should send them to the Institute and contribute along the lines that they are qualified to discuss.

Prof. W. C. Bauer (Northwestern University): We all know that the safety of a machine depends upon the non-breakdown point. Disintegration of a material means that a chemical change has taken

place in that material, and we all know that increase in temperature greatly increases chemical activity. It has been shown for temperature lying between 0 deg. C. and approximately 200 deg. C., the velocity constant for a given chemical action is increased two to three times for every 10 degrees of temperature rise. If we apply this to the case of the disintegration of insulating material, we find that if we assume a material to last ten years when continuously operated at, say, 70 deg. C., then when operated continuously at 80 deg. C. it would last only three to five years, and when operated at 90 deg. C. it would last approximately one to two years.

It is evident, therefore, that the ultimate temperature at which the insulation will be continuously operated is the important temperature.

I am certainly pleased to see that we are getting to some sane means of rating the machines as to ultimate temperature, because that really means the safe operating point of the material for a certain length of time, and I am glad to hear Mr. Lamme speak in such a pronounced way on that subject.

P. B. Woodworth, M. W. S. E.: The American Institute of Electrical Engineers has been publishing rules for some time, and the people, or the manufacturers, or both, have been making the rules, or rather, the rules have been following the people, than the people the rules. When a man like Mr. Lamme comes before us and says we should reverse the operation, I think we have good authority, especially as I happen to know that in a good many instances when people have wanted to build machines, on looking up the situation somebody has said to them, "You better not test that machine; it is covered by a Lamme patent." Then they tried something else, when someone would say, "You better not do that, there is a Lamme patent." In other words, I have heard that so many times I am quite sure there is one man who leads the people, and that man is Mr. Lamme.

B. H. Glover (Underwriters' Laboratories): I am pleased to note the recognition of the value of different insulation materials. The author spoke of mica as having been found equal to the high temperature requirements in machines, and also pointed out the limitations of the fibrous insulation. I would like to know what has been considered or discussed as the ultimate life or time in service of insulation. Insulation is limited as to life, by the temperatures attained, as has been very well pointed out. Mica will stand a higher temperature than the fibrous insulations, but I would like to know at what time or age mica would break down at the temperature mentioned in the rating standard. In laboratory work we often make what we call an endurance test. We test a snap switch or socket or other device a given number of times to see how it will "stand up" either electrically or mechanically, and to ascertain by such a test what features of design are unreliable or defective. In the determination of the proper temperature which is safe and

practicable with different insulations, has any consideration been taken of the time at which any such insulation would break down when operated continuously at a given temperature? I do not know that I have expressed myself clearly, but how long should a machine last if operated continuously at the proposed ratings that have been presented?

Mr. Van Hatton: I am glad we have a representative of the Board of Underwriters here this evening, because if he were not I am afraid when we came to this matter of rating and they said there was 100 deg. rise in the machine, they would not recommend the machine as of perfectly sound construction.

I would like to know how this rating will affect the manufacturer who desires to use some other insulation than that which is specified in the rules. For instance, a specification comes in for a 100 h. p. motor, and if the ultimate temperature rise is given as 100 deg. a manufacturer in using some other kind of insulation might be at a disadvantage in bidding on that particular motor. A different type of insulation might be better even than mica, and yet that man could not rate his machine; that is, he would be offering a better machine than the specifications called for.

A Member: When motors or machinery are placed in a factory where there is a great deal of acid vapor the windings are impregnated. Will you kindly tell us about how much longer a machine will last when windings are impregnated when subject to acid vapor than when they are not impregnated?

Mr. Lamme: You have asked a rather difficult question. The impregnation generally used is a gum which fills the small spaces in the insulation to keep out foreign materials. I do not know whether we can impregnate a coil so completely that an acid will not penetrate eventually, but we certainly can fill it up so that acid will not penetrate it easily or quickly. I do not know whether any of the impregnating gums will resist acid indefinitely. We simply know that the object of impregnation is to keep out foreign particles, such as moisture and other things. In impregnating the coils, which is done, of course, in a vacuum, we draw the air out and then immerse in a melted gum to fill the spaces.

Jos. Jacobson: In what class do you put enamel insulation, such as is used on enamel wire? Does that stand a very high temperature?

Mr. Lamme: Wherever enamel will stand 150 deg. C. we would put it in the "mica or equivalent" class.

Mr. Jacobson: It would stand much higher than that.

Mr. Lamme: Possibly much higher. We have as yet given only two classes. If higher classes are advisable, they will doubtless be added later. But I do not know of any practice which runs windings at higher than 150 deg. C. Rheostats do not come under the two classes I have given. We will probably add a third class to cover the insulation in heating apparatus where we run up to

almost the point of incandescence. We will add to these classifications as we get data. As I said before, the object is not to shut out any class, but to add it as we find out more about it.

The Author: To Mr. Glover's question on the temperature of insulation, we cannot give a very definite answer. We have classed insulations in two general groups. One class includes fibrous or cellulose materials, and in the other we have included mica and equivalent materials. For the fibrous type we have obtained all the experience of various engineers who could give us any data; we have gone over our own experience; we have then compared all the data available, and have concluded that 100 deg. C. would give a relatively long life for such insulations. Whether it is ten years or fifteen years, we do not know, but it is a long life. We know of insulations running over 100 deg. for several years, and we have instances in transformers which, in actual test, are running very close to 100 deg., and in which, after running many years, the material appeared to be in good shape. But it is difficult to get exact data, because in many cases we have not known the true internal temperature. However, we have lined up all the data as well as we could.

With higher temperatures, in fibrous insulations, we have been able to get more accurate data, because it takes a shorter total period to deteriorate the insulation. For instance, at 150 deg. C. you can determine the life of an insulation in a short time, because it is only a comparatively short time before the insulation is in very bad shape. At 125 deg. C. you can get fairly reliable data in a few months' time. By taking a number of such points, we plotted a curve as an approximation, and the prolongation of that curve for lower temperatures showed that it lies very close to the 100 deg. C. value for a relatively long life,—say ten years or more. The only points we can determine accurately on such a curve, are the higher temperatures, because at the lower temperature it takes too long. If the insulation is good for ten years, then we have to test for ten years to find it out.

Mica has now been used for some years for high temperature insulations. We have had field coils of turbo-generators, where, with fibrous insulations, the insulation would break down in six months' time, due to temperatures materially over 100 deg. C. We have found cases of 125 deg. C. for three months steadily; at the end of that time the insulation was ruined, showing that in three months fibrous insulation would be ruined. We have put mica insulations on the same machines and operated them three or four years with no sign of deterioration. We have operated fields of the same type at 150 deg. C. for two or three years, with no sign of trouble. We have operated at 250 deg. C. from 20 to 40 hours with no sign of deterioration. So we do not yet know what the upper limits are. But we do know that 150 deg. C. for two years has not shown any deterioration as far as we can find out; that 125

deg. for four or five years has not shown any trouble. So we can only draw a curve through such points that we know, and in that way we can approximate at least a safe curve. But I am inclined to believe that with mica we have put our limits too low. The probabilities are that we will eventually go higher if there is any occasion to do so, but we may reach a point after a while where the total increase in the resistance of the copper is so great that it will not pay to run at any higher temperatures, except in cases of emergency. So there is a possibility we may not work our material much higher than now. What we want is to get, at present temperatures, some insulation which is durable. We have been able to determine that, as I said before, by operating at higher temperatures for short periods; for with mica insulations, we have not been in the business long enough to find the real life at the temperatures now used.

As to insulations other than fibrous and mica,—if such are developed, and sufficient data are obtained to show that the material will stand more than 150 deg. C. and, if that material proves to be a good one otherwise, then eventually it will be put in a separate class in the standardization rules. We have no intention of shutting out anything. We simply want to get as simple a classification as we can. Possibly at some future time there will also be an intermediate class between 100 deg. C. and 150 deg. C., but at the present time we have not enough data to make any such classification.

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Extra Meeting March 31, 1913.

An extra meeting of the Society (No. 819) was held Monday evening, March 31, 1913. The meeting was called to order about 8:20 p. m. by President Reichmann, who introduced Professor Rolin D. Salisbury to the meeting. Professor Salisbury had but recently returned from an extended trip through parts of South America, particularly Patagonia, where he had been making some geological researches, etc. By the aid of many beautiful lantern slide pictures, Professor Salisbury gave a very interesting account of his trip. After the conclusion of the lecture, refreshments and cigars were offered, and a social time was enjoyed by those present.

Regular Meeting, April 7, 1913.

The regular meeting for April 7 was postponed for lack of a paper to be presented.

Extra Meeting, April 14, 1913.

An extra meeting of the Society (No. 820), the Bridge and Structural Section, was held Monday evening, April 14, being called to order by Mr. I. F. Stern, Chairman, and with about 45 members and guests in attendance.

The Chairman explained that this was an adjourned meeting from that held December 9, 1912, when Prof. O. H. Basquin presented his paper on Columns. There was some little general discussion, and Professor Basquin gave a condensation of, and replied to certain parts of the paper for the evening, which consisted of written discussion of the subject of Columns, received from various sources.

The Chairman and Messrs. F. E. Davidson, J. G. Kreer, J. H. Hayford, P. W. Leisner, F. G. Vent, and O. H. Basquin took part in the discussion. Meeting adjourned at 10:35 p. m.

Extra Meeting, April 21, 1913.

An extra meeting of the Society (No. 821)—the Hydraulic, Sanitary, and Municipal Section—was held Monday evening, April 21, 1913. The meeting was called to order at 8:30 p. m. by Mr. Langdon Pearse, Chairman, and with about 45 members and guests present. The Chairman read a letter from Mr. Geo. F. Swain, President Am. Soc. C. E., calling attention to the Fifth National Conference on City Planning to be held in Chicago May 5-7, 1913.

The Chairman then introduced Mr. George L. Thon, M. W. S. E., who read the paper written jointly with Mr. L. R. Howson on "The Yield of a Kentucky Watershed."

Mr. Samuel A. Greeley was then introduced, who read his paper (in abstract) on, "A Brief Discussion of Rainfall and its Run-off into Sewers." Discussion followed from Messrs. C. B. Burdick, J. H. Hayford, L. R. Howson, C. D. Lewis, C. C. Spencer, L. K. Sherman, and S. A. Greeley.

Meeting adjourned at 10:15 p. m.

LIBRARY NOTES

The Library Committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts, the following have been received:

MISCELLANEOUS GIFTS.

- The Banks Law Publishing Co., New York:
Valuation of Public Service Corporations, Robert H. Whitten. Cloth.
- McGraw-Hill Book Co.:
Descriptive Geometry, Miller & Machlin. Cloth.
- Follet L. Greeno, Rochester, N. Y.:
Obed Hussey, Who of All Inventors Made Bread Cheap. Cloth.
- Bion J. Arnold, M. W. S. E.:
Report on the Value of Properties of Metropolitan Street Railway System of Kansas City, Mo. Cloth.
Report on an Interurban Railway Terminal System for Cincinnati, Ohio. Cloth.
- B. F. Affleck:
The Concrete House and Its Construction, M. M. Sloan. Cloth.

EXCHANGES.

- Ohio State University:
Bulletin No. 8, Stress in Tall Buildings, C. A. Melick. Pam.
Commemoration Bulletin, Dept. of Civil Engineering. Pam.
- Colorado State Bureau of Mines:
12th Biennial Report, 1911-12. Cloth.
- Wisconsin Railroad Commission:
Various Reports and Findings. Pams.
- Canada Department of Mines:
Investigations of the Peat Bogs and Peat Industry of Canada. Pam.
- American Railway Bridge and Building Association:
Proceedings 22nd Annual Convention, 1912. Pam.
- Ohio State Highway Department:
Bulletin No. 17, Earth Roads. Pam.
- Ohio State Geological Survey:
Geology of the Columbus Quadrangle. Cloth.
- South Park Commissioners, Chicago:
Annual Report, 1912. Pam.
- American Society of Agricultural Engineers:
Transactions, 1910. Pam.
- American Electrochemical Society:
Transactions, 1912. Pam.
- Society for the Promotion of Engineering Education:
Proceedings, 1912. Cloth.
- Metropolitan Sewerage Commission, New York:
Preliminary Reports, 6 and 7. Pams.
- Engineering Association of the South:
Proceedings, Jan.-Mar., 1913. Pam.

GOVERNMENT PUBLICATIONS.

- U. S. Coast and Geodetic Survey:
Report of Superintendent, 1912. Cloth.
- U. S. Bureau of Mines:
Bulletins Nos. 52, 63, 65. Pams.
Technical Papers Nos. 31, 36, 40. Pams.
- U. S. Geological Survey:
Geological Folios Nos. 184, 186.

MEMBERSHIP

Additions:

Bell, Victor H., Valparaiso, Ind.....	Student	Member
Chase, Carl W., Gary, Ind.....	Member	
Hall, Edwin C., Chicago.....	Member	
Hammer, Mahlon J., Chicago.....	Member	
Hansen, Paul, Urbana, Ill.....	Member	
LaBach, Paul M., Chicago.....	Member	
Lowenberg, Max L., Chicago.....	Junior	Member
Pearl, James W., Chicago.....	Member	
Stout, Samuel E., Gary, Ind.....	Associate	Member
Weiss, Charles L., Chicago.....	Junior	Member
Yeoman, Ray C., Valparaiso, Ind.....	Associate	Member

Deaths:

Dance, M. H., December 19, 1912.
 Sanne, Oscar, April 4, 1913.

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No. 5

DESIGN OF AN ARCH SYSTEM BY THE METHOD OF THE ELLIPSE OF ELASTICITY

A. C. JANNI, C. E.

Presented January 13, 1913.

The usual methods employed in designing an elastic arch render it impossible to study the arch separately from assumptions as to loading. In other words, in commencing the design of any arch by the usual methods, it is necessary not only to consider the shape of the arch, but also the amount and distribution of the load coming upon it. This is extremely laborious, since any change in the loading assumed makes it necessary to repeat from the beginning the computation of the stresses.

The method here presented is a purely graphical one and holds irrespective of the geometrical form of the axis of the arch, irrespective also of the law of variation of cross section of the latter, and of the assumptions of loading. In this paper the application of this method to the design of the Kingshighway Viaduct,* in St. Louis, will be given. The underlying theorems are to be found in an Appendix to this paper.

The Viaduct has been designed under the assumption, which is in accordance with the fact, that the three main arches, with their corresponding piers, act as a single elastic system. However, for the sake of brevity, we shall develop the method as applied to the central 170 ft. arch only, afterwards explaining in a few words the extension of this method to the main arch system as a whole.

The important dimensions of the span, which is being discussed, are as follows:

Span	170.00 ft.
Rise	17.00 ft.
Thickness at the key.....	2.80 ft.
Thickness at the spring.....	3.50 ft.
Intrados radius	221.00 ft.
½ Geom. axis	87.85 ft.

*Full description of the viaduct is to be found in *Engineering News*, June 27, 1912.

The first step is to divide the arch into an arbitrary number of voussoirs, so taken that each voussoir can be considered as approximately of constant cross-section. In this particular case the half span has been divided into ten voussoirs, each being 8.78 ft. long along the geometrical axis.

Then calculate for each voussoir the following quantity:

$$w = \frac{\Delta s}{EI},$$

where

Δs is the length along the geometrical axis and is the same for all voussoirs;

E is the modulus of elasticity of the material of the arch, which also is constant for all voussoirs; and

I , the moment of inertia of the cross-section at the center of gravity of the voussoir, is, of course, variable.

The quantity w is known as the "elastic weight" of the voussoir.

Tabulations of the values of I and w follow:

$I_1 = 2.98$	$I_6 = 3.68$
$I_2 = 3.04$	$I_7 = 3.96$
$I_3 = 3.10$	$I_8 = 4.33$
$I_4 = 3.20$	$I_9 = 4.71$
$I_5 = 3.48$	$I_{10} = 5.12$
$w_1 = \frac{8.78}{2.98} = 2.94$	$w_6 = \frac{8.78}{3.68} = 2.38$
$w_2 = \frac{8.78}{3.04} = 2.88$	$w_7 = \frac{8.78}{3.96} = 2.21$
$w_3 = \frac{8.78}{3.10} = 2.83$	$w_8 = \frac{8.78}{4.33} = 2.02$
$w_4 = \frac{8.78}{3.20} = 2.66$	$w_9 = \frac{8.78}{4.71} = 1.86$
$w_5 = \frac{8.78}{3.48} = 2.52$	$w_{10} = \frac{8.78}{5.12} = 1.71$

(In the above values of w , E , for the sake of simplicity, has been assumed equal to unity. The value of E has no importance except when considering temperature stresses, in which case the assumed value of E must be given due weight as we shall show.)

Now, for each voussoir, there exists a particular ellipse, the "ellipse of elasticity," its center coinciding with the center of gravity

of the voussoir. In this case the major axis of the ellipse coincides with the geometrical axis of the arch.

The value, ρ_a , of the major axis is $\Delta s \sqrt{\frac{1}{12}}$

The value, ρ_b , of the minor axis is $\sqrt{\frac{I}{A}}$, where

A equals the area of the cross section of the voussoir, and Δs and I have the same significance as above.

The following tables give the values of A and ρ_b ; ρ_a being the same for all voussoirs, and having the value $8.78 \sqrt{\frac{1}{12}} = 2.54$.

$$A_1 = 3.72 \text{ sq. ft.}$$

$$A_6 = 3.94 \text{ sq. ft.}$$

$$A_2 = 3.74$$

$$A_7 = 4.02$$

$$A_3 = 3.76$$

$$A_8 = 4.12$$

$$A_4 = 3.82$$

$$A_9 = 4.22$$

$$A_5 = 3.88$$

$$A_{10} = 4.32$$

$$\rho_{b1} = \sqrt{\frac{2.90}{3.72}} = 0.89 \text{ ft.}$$

$$\rho_{b6} = \sqrt{\frac{3.68}{3.94}} = 0.96 \text{ ft.}$$

$$\rho_{b2} = \sqrt{\frac{3.04}{3.74}} = 0.90$$

$$\rho_{b7} = \sqrt{\frac{3.96}{4.02}} = 0.99$$

$$\rho_{b3} = \sqrt{\frac{3.10}{3.76}} = 0.91$$

$$\rho_{b8} = \sqrt{\frac{4.33}{4.12}} = 1.02$$

$$\rho_{b4} = \sqrt{\frac{3.29}{3.82}} = 0.92$$

$$\rho_{b9} = \sqrt{\frac{4.71}{4.22}} = 1.05$$

$$\rho_{b5} = \sqrt{\frac{3.48}{3.88}} = 0.94$$

$$\rho_{b10} = \sqrt{\frac{5.12}{4.32}} = 1.09$$

PRELIMINARY INVESTIGATION.

Pressure Polygon For Dead Loads.

After tentatively deciding upon the main details of the arch, such as its span, thickness at spring and key, and the percentage of steel, it is possible, before entering into an exhaustive study of the arch, to make certain preliminary investigations which will serve later as a method of checking subsequent work and give immediately a criterion by which the designer may judge as to the probable adequacy of the dimensions assumed.

Draw for each voussoir (Fig. 1) the axes of the corresponding ellipse of elasticity. Then consider that the elastic weights found as above are horizontal forces, each applied at the center of its corresponding voussoir. Let us find the center of gravity of this system of forces as well as the static moments of the forces with respect to the horizontal passing through the center of gravity.

In order to accomplish this, we lay off on an arbitrary horizontal line the elastic weights calculated as above and take an

arbitrary pole P_1 , projecting from it the elastic weights. Then connecting the horizontals passing through the centers of gravity of the voussoirs draw the funicular polygon p_1 , corresponding to the pole P_1 . We have, then, in G , the point of intersection of the first, or vertical, and last, or closing, side of this polygon, the center of gravity of the system of elastic weights considered as forces. The successive sides of the funicular polygon cut, on the horizontal through G , segments proportional to the static moments of the corresponding elastic weights, with respect to this horizontal.

Next, considering the horizontal through G as polar, find for each ellipse whose semi-axes have been laid out as above the corresponding anti-pole, $H_1, H_2, \dots H_{10}$ respectively. Assuming another pole P_2 , and treating as horizontal forces applied at the anti-poles, $H_1, H_2, \dots H_{10}$, the static moments found as above, construct the corresponding funicular polygon, p_2 . The distance $\frac{1}{2}n$, between the first and last sides of the polygon p_2 , is proportional to the inertial moment of the system of elastic weights, referred to the horizontal passing through G .

In the table below are given the dead loads calculated from the data of the design:

I	2.463 tons	XI	1.019 tons
II	1.870	XII	2.054
III	0.772	XIII	1.341
IV	2.888	XIV	2.120
V	0.156	XV	1.371
VI	1.922	XVI	2.186
VII	1.023	XVII	1.404
VIII	1.962	XVIII	2.252
IX	1.000		
X	2.001	Total.....	29.804 tons

On an arbitrary vertical (O-XVIII at the left) let us lay off these loads, starting from the point O , and on the horizontal OG let us assume the point P_0 as pole. Draw the funicular polygon p_0 intersecting with the verticals through the points of application of the loads and with respect to the pole P_0 . Let us load the polygon p_0 horizontally with the same elastic weights as determined for the arch at the points where the verticals through the centers of gravity of the voussoirs meet with the polygon p_0 . Then intersecting these horizontals, draw the funicular polygon p_1' , using the same pole, P_1 , thus obtaining G_1 , the center of gravity of this new elastic system. If we again load horizontally the polygon p_0 with the same static moments found as above, and at the meeting points of the verticals through the anti-poles with the sides of the polygon p_0 , construct the funicular polygon p_2' , intersecting these horizontals, we shall have the distance $\frac{1}{2}n_1$, between the first and last sides of p_2' . This distance is proportional to the inertial moment of the elastic weights acting on this new elastic system, in the same

manner as $\frac{1}{2}n$ is proportional to the inertial moment of the system of elastic weights with respect to the horizontal passing through G .

Since the distance OP_o , except by accident, could not be equal to the true thrust, the polygon p_o is not the true pressure polygon. Between the polygon p_o and the true pressure polygon p there is, however, a geometrical relation; they are homological by affinity

and the ratio of their affinity is given by $\frac{n}{n_1}$. Therefore the distance of any point on the true pressure polygon p from the horizontal through G can be obtained by multiplying by the ratio of affinity $\frac{n}{n_1}$, the distance from the horizontal through G_1 , to the point of the polygon p_o on the same vertical with the point in question. In

this instance $\frac{1}{2}n = 1.91$ in., $\frac{1}{2}n_1 = 2.21$ in. Therefore $\frac{n}{n_1} = 0.86$.

Taking, for example, the intersection of the polygon p_o with the vertical through G , we find this to be equal to 1.85 in. The corresponding point of the true pressure polygon, p , will be on the same vertical and at a distance from G equal to 0.86×1.85 in. = 1.59 in., which locates definitely the point of intersection of the true pressure polygon with the key. The true horizontal thrust, likewise, will be found by multiplying the assumed thrust (60 tons) by the inverse of the ratio of affinity, or

$$H = \frac{n_1}{n} \times 60 = 1.16 \times 60 = 69.60 \text{ tons.}$$

The true pressure polygon is perfectly determined by the data above obtained and can be drawn as shown in Fig. 1.

The formulæ from which are calculated the stresses existing in sections I, II and III are:

$$\sigma_e = \frac{M_n}{A \delta_e} \quad (\text{extrados})$$

$$\sigma_i = \frac{M_m}{A \delta_i} \quad (\text{intrados})$$

where

M_n and M_m are the kernel moments,

A is the area of the section,

δ_e is the distance from the center of gravity of the section to the kernel point n ; and

δ_i is the distance from the center of gravity to the kernel point m . We may calculate, therefore, the values given in the following table:

Stresses Due to Dead Load.

Section	Lb. σ_e per sq. in.	Lb. σ_i per sq. in.
I	—109	—236
II	—316	—208
III	—260	—260

TEMPERATURE STRESSES.

The horizontal thrust due to change of temperature will pass through the center of gravity, G , of the elastic system, and will be given by

$$H = \frac{a t^0 E l}{\sum \frac{\Delta s}{I} y_1 y_2}$$

where

a = coefficient of expansion 0.0000066;

E = modulus of elasticity 144,000 tons;

l = chord of the geometrical axis 171.3 ft.;

$\sum \frac{\Delta s}{I} y_1 y_2$ = moment of inertia of the whole elastic system,

with respect to the horizontal passing through G ; y_1, y_2 , being the polar distances, respectively, from P_1 and P_2 , so that:

$$\sum \frac{\Delta s}{I} y_1 y_2 = 2 \times 1.91 \times 24 \times 12 = 1100.16$$

we have therefore

$$H = \frac{0.0000066 \times 144000 \times 171.3}{1100.16} t^0 = 0.147 \times t^0$$

and for 20 degrees change of temperature, we will have

$$H_{20^0} = 2.94 \text{ tons.}$$

Therefore, for the sections I and III, using the same formulæ as above, the following maximum tensile and compressive stresses are found:

Stresses Due to Range of Temperature of 40 Degrees F.

Section	Lb. σ_e per sq. in.	Lb. σ_i per sq. in.
I	± 134	∓ 94
III	± 81	∓ 103

From these data one can judge as to whether or not this arch as tentatively designed will be capable of withstanding the stresses generated by the addition of the live load.

The effect of shrinkage of concrete in setting, and of the shortening of the geometrical axis due to striking of the false-work,

has been considered in this design as a sinking of the key resulting from a lowering of the temperature. This virtual drop in the temperature has been added to the change in temperature assumed in the data of the design. In this case the virtual drop amounted to 36 degrees, producing the following stresses in Sections I and III, the stresses in Section II being negligible:

Stresses Due to Shrinkage Caused by Setting and Dead Load.

Section	Lb. σ_e per sq. in.	Lb. σ_l per sq. in.
I	+242	—165
III	—145	+184

COMPLETE METHOD FOR THE DESIGN OF THE ELASTIC ARCH.

The preceding preliminary work has served to indicate to us the probable condition of stability of the arch, and warrants us, if the indications are satisfactory, in investigating fully the effect of the live load; and the preliminary study alone might be sufficient in the case of a masonry highway arch, where the stresses generated by the live loads are in general small, in comparison with those generated by the dead load of the arch.

Figure 2 represents one-half of the span of the same arch previously treated. It has been divided in the same manner and the values A , I , w , Δs , ρ_a and ρ_b will therefore have the same values as above calculated.

For a complete analysis of the arch, five funicular polygons, p_1 to p_5 , must be constructed, as follows:

Polygon p_1 : Consider the elastic weights as vertical forces applied to the centers of gravity of their respective voussoirs. Now let us find the static moments of these elastic weights, considered as forces, when referred to the vertical passing through the center of the arch.

Lay off in their proper order on any arbitrary vertical at the left of the drawing the ten elastic weights, and, assuming as pole the point P_1 , at a distance equal to the sum of the elastic weights of the whole arch (that is Σw), construct a funicular polygon p_1 , intersecting the vertical lines of action of these elastic weights.

The intersection of the sides of this funicular polygon with the vertical through the center of the arch will determine the static moments of each elastic weight with respect to this vertical.

Polygon p_2 : The polygon p_2 is in every particular the same as the polygon p_1 constructed in Fig. 1 for the dead load.

Polygon p_3 : Let us locate the anti-poles V_1 to V_{10} of the vertical, through G with respect to the ellipse of elasticity of each voussoir. Considering the static moments found by the polygon p_1 as vertical forces applied to the points V_1 to V_{10} , construct a funicular polygon connecting them, using an arbitrary pole P_3 for this purpose.

Polygon p_4 : This polygon is similar in most respects to the

polygon p_2 of Fig. 1. There is this difference, however: The polar distance in polygon p_2 of Fig. 1 was arbitrary, but in this case the polar distance was equal to the vertical distance between the first and last sides of the polygon p_3 , as is indicated in the drawing.*

Polygon p_5 : Let us regard the static moments, considered as forces, which were used in constructing polygon p_4 , as applied vertically instead of horizontally to the same points ($H_1, H_2, \dots, H_{10}$, of Fig. 2).

Then lay off these moments on the vertical through G (for convenience of drawing), and assume a pole P_5 , at a distance from that vertical equal to the horizontal distance between the first and last sides of the complete polygon p_4 , or

$$2 \times \frac{1}{2}n = n.$$

With these vertical forces construct a funicular polygon p_5 with respect to the pole P_5 .

From the polygons p_1, p_3 and p_5 , we may obtain for unit loading at any point, the moment, the vertical reaction at the springs, and the horizontal thrust at the key. For instance, the vertical drawn through the point IV' gives M_{1v}, B_{1v}, A_{1v} and H_{1v} ; M_{1v} being the moment; A_{1v} , the vertical reaction at the left; B_{1v} , the vertical reaction at the right; and H_{1v} , the horizontal thrust at key.

It is therefore easy to construct the intersection and the envelope lines. For instance, considering again the vertical through IV' : A_{1v} and B_{1v} are the two vertical reactions, and H_{1v} the horizontal thrust at the key, when the unit load is located at this point. Laying off H_{1v} horizontally as in the drawing and joining the point IV' to the ends of A_{1v} and B_{1v} , we will have R_1 and R_r , which are the left and right reactions, respectively, in their true directions and magnitudes.

It now remains to locate the true intersection and envelope lines. Knowing the moment M_{1v} , we have

$$M_{1v} = R_1 \times d,$$

where d will be the distance from R_1 to G . In this particular instance,

$$d = \frac{M_{1v}}{R_1} = \frac{35.0}{2.09} = 16.74 \text{ ft.}$$

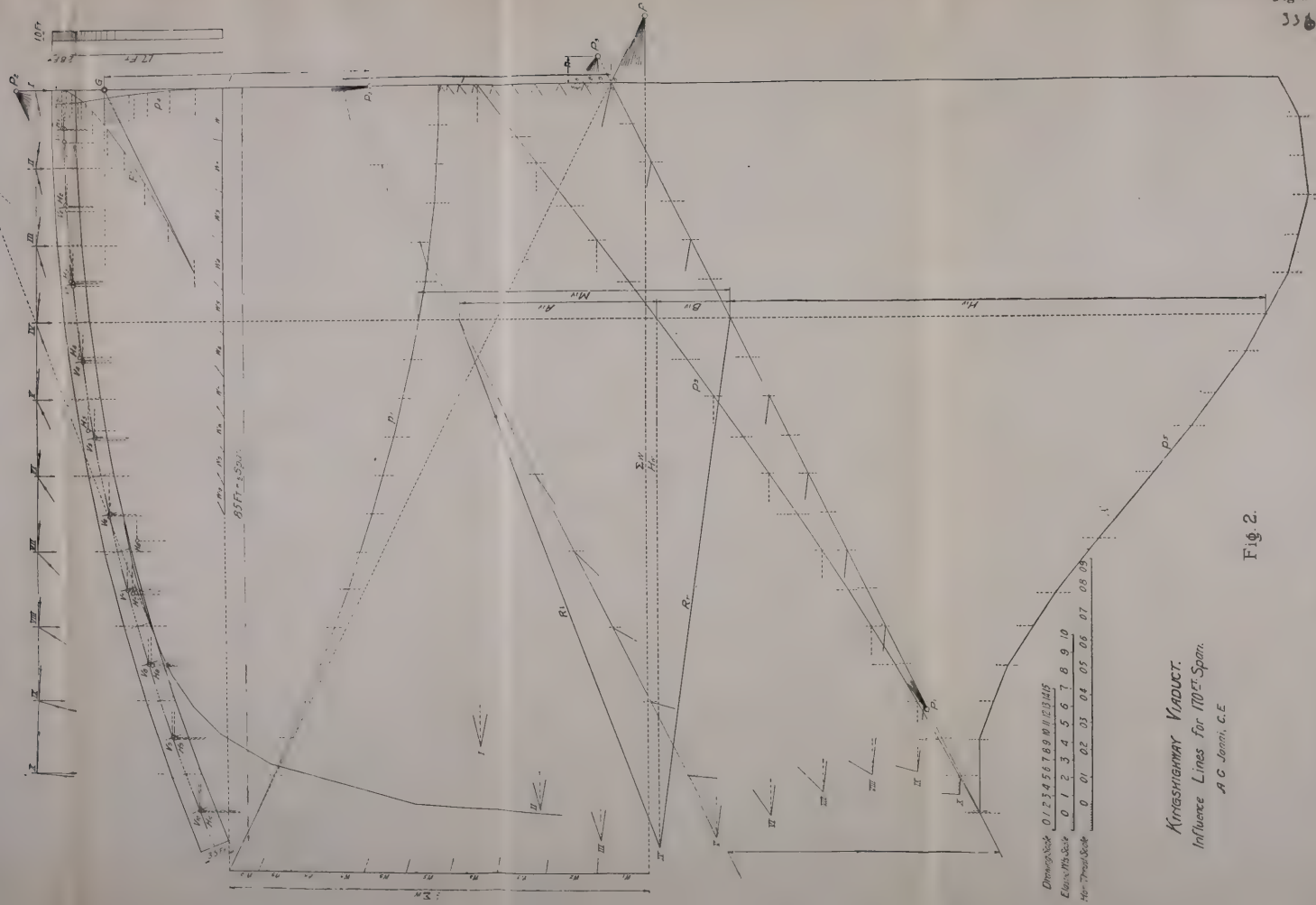
With a radius equal to d , draw a circle with G as a center, and a tangent to this circle, parallel to R_1 . The intersection between this tangent and the vertical through the point of application of the load will locate the point IV' , which is a point of the intersection line, the tangent itself forming a side of the polygon tangential to the envelope line. A similar construction has been followed for

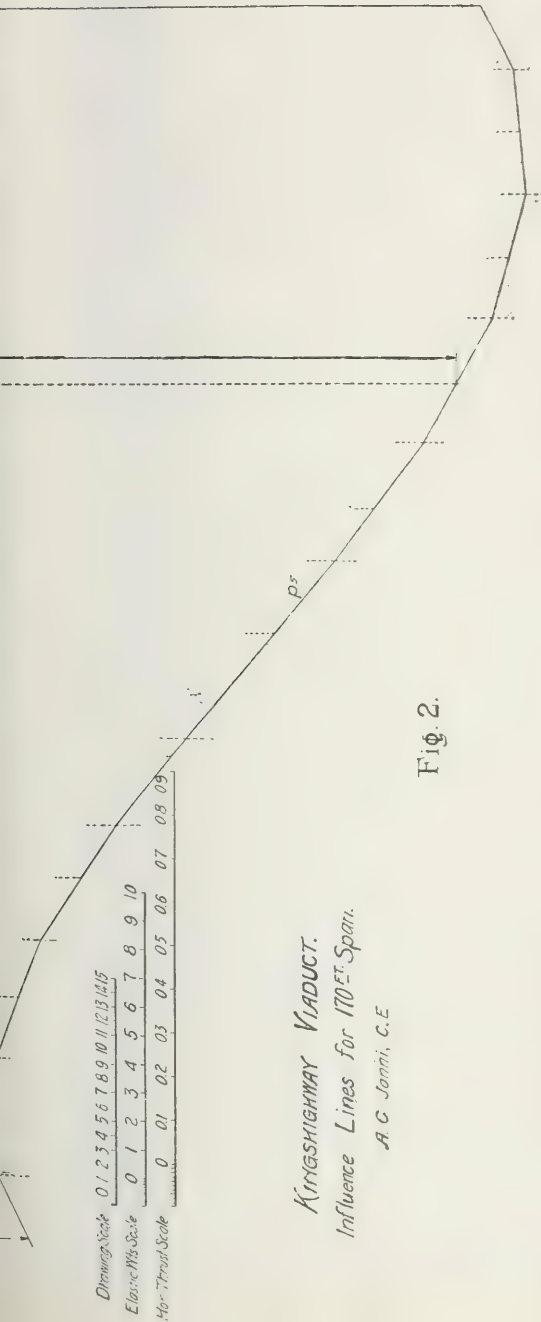
*When the arch is very flat, as in our case, the designer, after completing polygons p_2 and p_4 , should check the results given by them analytically, as the intersections are not advantageous and may lead to cumulative errors.

ENGINEERS
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System

Fig 2

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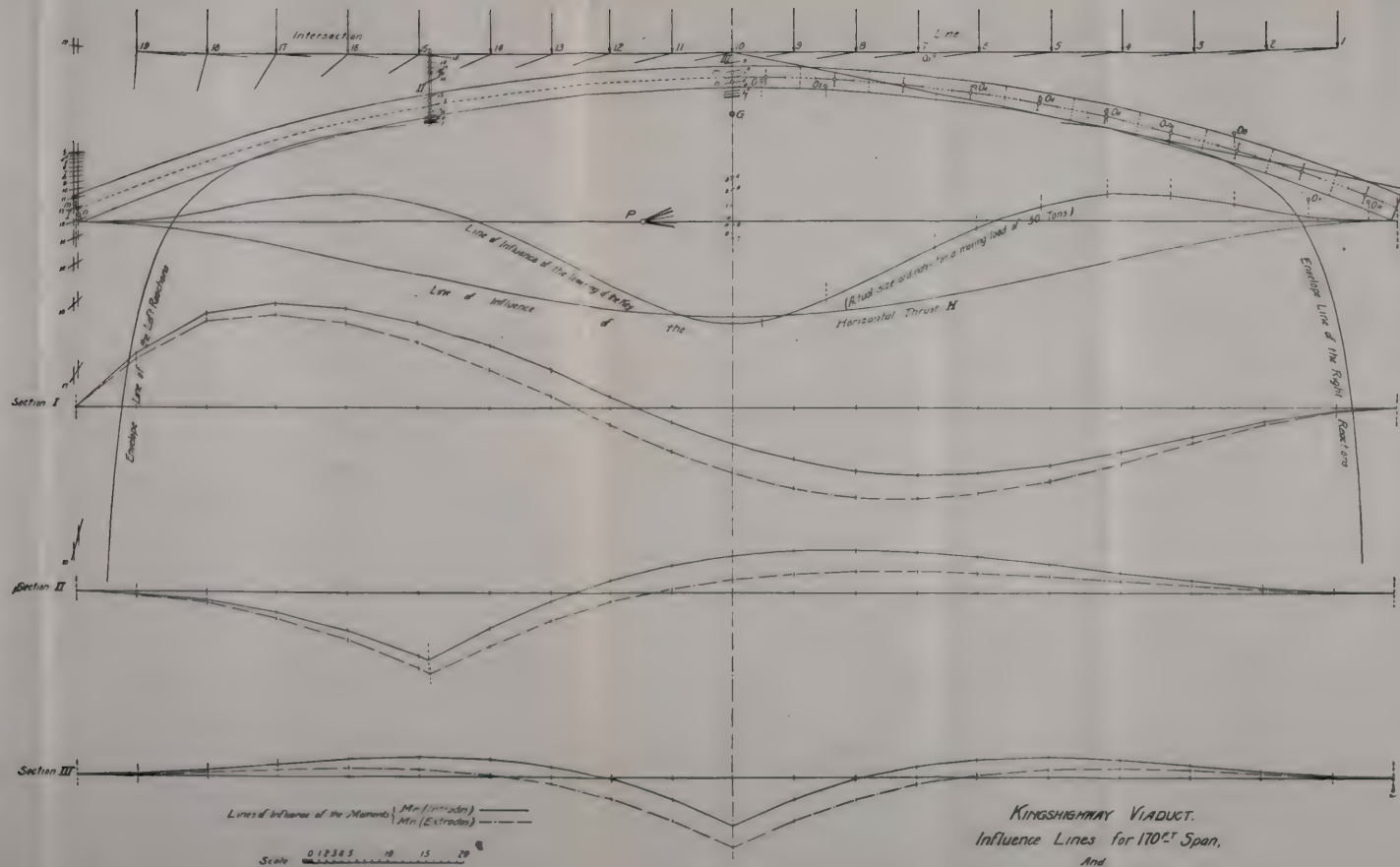


Fig. 3.

KINGSHIGHWAY VIADUCT.
Influence Lines for 170' Span,
And
Influence Lines for Sections I, II, III
A. C. Janni, C. E.

R_r , and an analogous method is to be followed for the points other than IV .

In Fig. 2 the entire construction for a unit load in position IV is carried out. In a similar manner the points $I, II, \dots, X$, have been determined, and the line of intersection and the left envelope line drawn.

It should be noted, that in locating the positions of the points $I, II, \dots, X$, the unit load was considered as acting through the points of intersection of the geometrical axis with the planes dividing the voussoirs. This was done because the polygons p_1 and p_3 are very nearly, and because polygon p_3 is actually, a true envelope tangent at these points to the true envelope curves which they approach as limits when the lengths of the voussoirs become infinitesimal.

The polygon of pressure due to the dead loads and found as shown previously by means of Fig. 1, can be checked by the data given in Fig. 2, using the polygons p_1 and p_3 , in the following manner: Locate on the arch in Fig. 2 the lines of action of the dead loads as shown in Fig. 1. Then the segments cut on these verticals by the sides of the polygon p_1 will give us the moments caused by unit loads at the corresponding points, and multiplying each moment so found by the actual corresponding dead load on that vertical, we find the real moment due to that load. The same method, using the horizontal thrust polygon p_3 , will give us the horizontal thrust caused by the actual loading at each point.

MOMENT POLYGON p_1 .

2.463	$\times 19.55$	$= 48.15$
1.870	20.05	37.49
0.772	20.10	15.52
2.888	21.10	60.94
0.156	22.10	3.45
1.922	22.65	43.53
1.023	22.90	23.43
1.962	24.80	48.66
1.000	25.10	25.10
2.001	27.20	54.42
1.019	27.90	28.43
2.054	30.10	61.83
1.341	31.15	41.77
2.120	33.30	70.60
1.371	34.90	47.84
2.186	36.85	80.55
1.404	39.00	54.76
2.252	40.75	91.77

$$\Sigma P = 29.804 \qquad 838.24$$

2

$$1676.48 = \Sigma M$$

HORIZONTAL THRUST POLYGON p_5 .

$$2.463 \times 2.41 = 5.936$$

$$1.870 \quad 2.30 \quad 4.301$$

$$0.772 \quad 2.29 \quad 1.767$$

$$2.888 \quad 2.08 \quad 6.007$$

$$0.156 \quad 1.90 \quad 0.296$$

$$1.922 \quad 1.78 \quad 3.421$$

$$1.023 \quad 1.75 \quad 1.790$$

$$1.962 \quad 1.44 \quad 2.825$$

$$1.000 \quad 1.38 \quad 1.380$$

$$2.001 \quad 1.07 \quad 2.141$$

$$1.019 \quad 0.98 \quad 0.998$$

$$2.054 \quad 0.71 \quad 1.458$$

$$1.341 \quad 0.60 \quad 0.805$$

$$2.120 \quad 0.40 \quad 0.848$$

$$1.371 \quad 0.28 \quad 0.384$$

$$2.186 \quad 0.15 \quad 0.327$$

$$1.404 \quad 0.06 \quad 0.084$$

$$2.252 \quad 0.01 \quad 0.022$$

$$34.790$$

$$2$$

$$69.580 = \Sigma H.$$

The total horizontal thrust, ΣH , and the sum of all the moments, ΣM , due to the dead loads, are shown above. It may be seen that the horizontal thrust found by this method is within 0.02 of a ton of that found from the construction shown in Fig. 1. Having both ΣM and ΣH and with $\Sigma P = 29.804$ tons, it is simple to find the coördinates of the total reaction of the arch with respect to the center of gravity G .

$$x = \frac{\Sigma M}{\Sigma P} = \frac{1676.48}{29.804} = 56.25 \text{ ft.}$$

$$y = \frac{\Sigma M}{\Sigma H} = \frac{1676.48}{69.60} = 24.09 \text{ ft.}$$

where

x is the distance from G to the point where the line of action of the resultant cuts the horizontal through G , and

y is the distance from G to the point where the line of action of the resultant cuts the vertical through G .

While the data in this case were determined from Fig. 2, the construction of the resultant was made on Fig. 1, in order to afford a check between this method and the one previously outlined in explaining Fig. 1. It may be seen, from inspection of Fig. 1, that the check is remarkably close, no distance being shown between the position last determined and that given before in the explanation of Fig. 1.

THE INVESTIGATION OF PARTICULAR POINTS

In investigating the effect of a live load with respect to particular sections, the entire arch is drawn as shown in Fig. 3, and on it are placed the envelope lines, the intersection line, and the line of influence of the horizontal thrust, which is really the envelope of the polygon p_5 —all these taken from Fig. 2. The first side of polygon p_5 corresponds to the horizontal through the point P in Fig. 3. In this particular design we considered nineteen positions of the live loads, and have computed the stresses due to the action of these loads, for the sections I, II, and III. The sections I, II and III are the same sections that have been considered in the determination of the effect of dead load and temperature.

Let us consider the influence on Section II of a unit load at point 12. The segment cut on the vertical through 12 by the horizontal line through P , referred to above, and the line of influence of the horizontal thrust, gives us the horizontal thrust due to a unit loading at 12. This amounts to 2.25 tons. Having the location 12, which is the intersection of the vertical through the load and the intersection line, we draw from that point a tangent to the envelope line of the left reaction. This cuts the vertical through the kernel point m , at Section II, as is shown on the drawing. The vertical distance from m to the point of intersection gives us to scale the lever arm of the moment about m , at II, generated by the unit load 12. This amounts to -0.72 ft. The moment, therefore, will be -1.620 ft. tons. On the vertical through 12 lay off -1.620 from an arbitrary horizontal. This is one point of the line of influence for the intrados for Section II, due to unit load in position 12. Similarly for the extrados we take our measurement from the point n ; the figures are $+2.25 T \times +0.52$ ft., $= 1.17$ ft. tons.

The table following was derived in this manner for the nineteen positions of loading considered for each of the sections I, II and III.

Position	H	Spring (Section I)				Section II				Key (Section III)			
		h_m	M_m	h_n	M_n	h_m	M_m	h_n	M_n	h_m	M_m	h_n	M_n
1	0.06	+6.70	+0.402	+8.17	+0.490	-2.88	-0.172	-1.63	-0.097	-3.20	-0.192	-2.00	-0.120
2	0.27	+6.53	+1.763	+8.00	+2.160	-2.86	-0.772	-1.62	-0.437	-3.05	-0.823	-1.85	-0.499
3	0.60	+6.25	+3.750	+7.70	+4.680	-2.83	-1.698	-1.60	-0.960	-2.70	-1.620	-1.55	-0.930
4	0.98	+5.85	+5.733	+7.35	+7.203	-2.80	-2.744	-1.56	-1.528	-2.40	-2.552	-1.18	-1.156
5	1.38	+5.40	+7.452	+6.88	+9.494	-2.75	-3.795	-1.52	-3.097	-1.90	-2.622	-0.70	-0.966
6	1.76	+4.77	+8.395	+6.25	+11.000	-2.72	-4.787	-1.46	-2.669	-1.30	-2.388	-0.12	-0.211
7	2.03	+4.25	+8.627	+5.75	+11.672	-2.64	-5.359	-1.38	-2.891	-0.65	+0.50	+1.319	0.50
8	2.25	+3.62	+8.145	+5.13	+11.542	-2.50	-5.625	-1.22	-2.745	+0.10	+1.30	+0.225	1.30
9	2.39	+2.80	+6.692	+4.32	+10.324	-2.30	-5.497	-1.00	-2.390	+1.22	+2.40	+2.915	3.80
10	2.44	+1.90	+4.636	+3.40	+8.295	-2.00	-4.881	-0.70	-1.709	+2.65	+3.80	+6.465	.....
11	2.39	+0.77	+1.840	+2.31	+3.592	-1.50	-3.585	-0.50	-0.478	.....	.....	.....	.....
12	2.25	-0.62	-1.395	-0.98	+2.295	-0.72	-1.670	+0.62	+1.170	.....	.....	.....	.....
13	2.03	-2.42	-4.872	-0.70	-1.421	+0.50	+1.015	+1.80	+3.654	.....	.....	.....	.....
14	1.76	-4.50	-7.920	-2.82	-4.963	+2.60	+4.576	+3.95	+6.952	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	+6.08	+8.694	.....	.....	.....	.....	.....	.....
15	1.45	.....	.....	.....	.....	.....	.....	+7.30	+10.585	.....	.....	.....	.....
16	1.38	-7.90	-10.902	-6.15	-8.487	+5.88	+8.114	+7.05	+9.729	.....	.....	.....	.....
17	0.98	-13.08	-12.818	-11.12	-10.897	+4.95	+4.851	+6.15	+6.027	.....	.....	.....	.....
18	0.60	-22.40	-13.440	-20.00	-12.000	+4.25	-9.550	+5.48	+3.888	.....	.....	.....	.....
19	0.27	-45.00	-12.150	-41.45	-11.191	+3.72	+1.004	+4.95	+1.236	.....	.....	.....	.....
.....	0.06	+20.55	+6.967a	+21.95	-6.283b	+3.50	+0.210	+4.72	+0.283	.....	.....	.....	.....

a20.55 × 0.06 = 1 × 8.2 = -6.967.

b21.95 × 0.06 = 1 × 7.6 = -6.283.

Assuming that the live load is 150 lb. per sq. ft., we are enabled to find the actual moments and from them the actual stresses as follows:

STRESSES DUE TO LIVE LOAD.

Section	Lb. σ_e per sq. in.		Lb. σ_i per sq. in.	
I	—190	+135	—135	+103
II	—174	+ 67	—150	+126
III	—110	+ 35	— 99	+ 49

Incidentally it might be well to mention that the data given in Fig. 3 afford still another check on the stresses due to the dead load as determined in the explanation of Fig. 1.

In order to locate cuspidal points of the influence lines more precisely in Section II, the live load was considered as passing through m and n , in turn.

These influence lines are polygonal from positions 1 to 6, and from 14 to 19; and curves from 6 to 14. This is due to the fact that the construction of the arch calls for concentrated loadings at the first mentioned points, and for a concrete fill between positions 6 to 14. It may therefore be assumed that the loads between 6 and 14 act as a continuous loading.

Take such simultaneous values of dead load, live load, and temperature stresses for the sections I and III as will produce a maximum stress in each of the respective sections. The maximum values are shown in the following table:

MAXIMA FOR SECTIONS I AND III.

Section	Lb. σ_e per sq. in.		Lb. σ_i per sq. in.	
I	+402		—630	
		—324	—204	
III		—596	+76	
		—289	—278	

It is evident that in sections in which tension is shown in the above table we are compelled to make further calculations (purely graphical also), to find the compression in concrete and the tension in steel, disregarding the tension in concrete, in accordance with the usual procedure. We obtain the following results:

Section	Tension in Steel.	Compression in Concrete.
I	14,000 lb. per sq. in.	810 lb. per sq. in.

INVESTIGATION OF DEFLECTION.

In this investigation we employ, besides the ellipse of elasticity, the principle of Maxwell.

Again referring to Fig. 3 let us draw the right reaction line for a unit force applied to the arch at position 10. For each voussoir then locate the anti-poles, $O_1, O_2, \dots, O_{10}$, of the ellipse of elasticity of each voussoir with respect to this reaction line. Let

us suppose that to the anti-pole O_1 is applied as elastic weight $\frac{I_{10}}{I_1} n_1$, regarded as a vertical force to the anti-pole O_2 , the elastic weight $\frac{I_{10}}{I_2} n_2$; . . . to the anti-pole O_{10} , the elastic weight $\frac{I_{10}}{I_{10}} n_{10}$; in these expressions $I_1, I_2, \dots, I_{10}$ have already been computed; and n_1 is the vertical distance, taken with the proper sign, from the center of gravity of the first voussoir to the reaction line above drawn; n_2 is the corresponding value for the second voussoir; . . . ; n_{10} , for the last.

The values for $\frac{I_{10}}{I_k} n_k$ are as follows; wherein $\frac{I_{10}}{I_k} n_k, k = 1, 2, \dots, 10$:

$$\begin{aligned}
 & + \frac{5.12}{2.98} \times 2.90 = +4.12 \\
 & + \frac{5.12}{3.04} \times 0.92 = +1.55 \\
 & - \frac{5.12}{3.10} \times 0.18 = -0.30 \\
 & - \frac{5.12}{3.29} \times 0.93 = -1.45 \\
 & - \frac{5.12}{3.48} \times 1.35 = -1.98 \\
 & - \frac{5.12}{3.68} \times 1.45 = -2.02 \\
 & - \frac{5.12}{3.96} \times 1.15 = -1.49 \\
 & - \frac{5.12}{4.33} \times 0.50 = -0.59 \\
 & + \frac{5.12}{4.71} \times 0.40 = +0.44
 \end{aligned}$$

$$+ \frac{5.12}{5.12} \times 1.72 = +1.72$$

On the middle vertical line through G lay off these values, with proper regard to sign, from the horizontal through P , and construct a force polygon with the pole P , taking the pole on this horizontal at

a distance $\frac{\lambda}{60}$, from the vertical. (1:60 is the scale of the drawing).

$$\lambda = \frac{E I_{10}}{H \Delta s} = \frac{144000 \times 5.12}{2.44 \times 8.78 \times 50} = 688.3$$

$$\begin{aligned} \text{Then the polar distance } \frac{1}{60} \lambda \text{ will be} \\ \frac{688.3}{60} = 11.47 \text{ ft.} \end{aligned}$$

Drawing the funicular polygon corresponding to this force polygon, with pole P , intersecting the verticals through $O_1, O_2, \dots, O_{10}$, will give us, to actual size (on the original drawing), the deflection of the key for each position on the arch of a moving load of 50 tons. That this line gives the true lengths of ordinates for a moving load of 50 tons follows from the fact that λ was divided by 50. By the principle of Maxwell, of course, this also represents the form of the geometrical axis of the arch when a load of 50 tons is applied at the crown. The deflection being proportional to the load, it is easy by the use of the proper ratio to find the deflection of the key where the assumed loading of 150 lb. per sq. ft. is applied to the arch; it was found to be 0.128 in. We are similarly able to determine that on striking the centers if the temperature is 65 deg. F. and there is no initial stress before this operation upon removing the centers, the dead load will produce a deflection at the key of 0.33 in.

RECAPITULATION.

It would be possible to reduce all stresses on the arch caused by dead load and live load from the lines of influence in Fig. 3, without resort to the pressure polygon drawn by the two different methods previously described and illustrated in Figs. 1 and 2. This polygon, however, besides being very useful for a quick preliminary trial of the stability of the arch under dead load, should not be omitted, because it gives to an experienced designer a graphical representation from which he may judge at a glance of the behavior to be expected under different conditions of live load and temperature, and it is easy for one familiar with the slide rule to make the few simple calculations necessary for its construction.

In the foregoing article we have applied the new method of the ellipse of elasticity to the investigation of the central arch of the Kingshighway viaduct. We have determined by easy graphical methods the influence lines for moments, vertical reactions and horizontal thrusts due to a unit load in any position on the arch, from which it is but a step to derive the corresponding values for any hypotheses of loading. Similar graphical methods have given the deflection of the geometrical axis of the arch under any loading.

In the final design of this viaduct, however, the theory of the ellipse of elasticity was applied in a more exhaustive form. The three large arches, together with the four corresponding piers (which all together form a monolithic structure), were regarded as a single elastic system, since a load on one of the arches has an effect on the adjoining ones, owing to the fact that the middle piers are of light construction.

CONCLUSION.

The rapid increase in the use of arch spans, especially in plain and reinforced concrete, during the last ten years, has more and more emphasized the fact that the application of the usual theories of the elastic arch is very laborious and the results obtained are limited by the preliminary hypotheses of loading assumed; the adoption of a second hypothesis entails a repetition of this work from the beginning, etc., and for everyday purposes this application is very unsatisfactory. Combinations of analytical and graphical methods have been devised depending upon certain arbitrary assumptions, which to some extent facilitate the application of the elastic theory to arch design. It is, of course, unnecessary to state that a purely graphical method has great advantages over analytical or combined analytical and graphical methods.

By the method of the ellipse of elasticity developed above, it is possible to draw the influence lines for moments with regard to any section. These influence lines show at once with respect to that section the most prejudicial hypothesis of loading, and this *independent of any assumptions*. In other words, the influence lines for moments and for vertical reactions and horizontal thrusts (polygons p_1 , p_2 and p_3 , Fig. 2), have been constructed absolutely independently of any hypothesis of loading, and are dependent solely upon the geometrical shape of the arch considered. They are *characteristics peculiar to the arch alone*, and they serve for the complete calculation of the stresses in any section caused by loading according to any hypothesis.

To have published the description of the application of the method to the design of the Kingshighway viaduct would have been difficult for me without the kind and able assistance of Mr. L. N. Beals. To this gentleman and to Mr. Mont Schuyler I am also indebted for invaluable aid in arranging this material and in giving it a form appropriate for English readers.

DISCUSSION.

I. F. Stern, M. W. S. E. (Chairman): I hope that the speaker's remarks with reference to our intimate knowledge of graphic statics will be justified by most of us. Going through the complicated mathematical analysis, which I fear has not been clear to all,—and I say that in all humility, because those of us who have been out in practical life and who have not had occasion to use the complicated analysis for some time are not conversant with it,—yet, having gone through that and established certain principles which appeal to us while they are being described, we must, unless we can analyze them ourselves or analyze them afterwards at our leisure, take them as facts, and we can then go ahead and apply the principles of graphic analysis. I, for one, am willing to coincide with the speaker that we know something about that, although I do not think that I would coincide with him in that we know more than he does upon that subject.

The matter of the analysis of the elastic arch has, of course, been one of the great questions that have confronted the analyst, and personally I have not been familiar with the method the speaker has used. The method I have used is that used by Professor Charles E. Greene, of the University of Michigan, who was one of the deans of graphical analysis in this country, and who was one of the originators of the area moments, which the author handles with great facility, although he has not called it by that name. His method, as you all know, is the graphical method of determining the three conditions—the inviolability of the span length, no yielding of the abutments, and the change of inclination neutralizing itself between the abutments. I have no doubt that many of us have used the latter method, and it has been my experience that after the proper constants have been determined, where the relation between the rise of the arch and the span has been taken as a certain quantity which is then used in analysis, the proposition is not very difficult of solution. However, we have had another side presented to us tonight, and I know that we are all very much interested in it.

Ernest McCullough, M. W. S. E.: The cry in commercial offices is for short methods of arch design, and several formulae (for one of which I am responsible) are in use. Some reinforcing steel companies also issue diagrams and tables by means of which engineers who do not specialize in arch design may prepare plans in an hour or less. Probably every man who has done any designing in reinforced concrete has used some of these short methods and never later investigated to see if the steel put in was required. That is, the greater number of reinforced concrete bridges in the country really required no steel provided the abutments were immovable. One engineer complained to me that he had made a careful search for data on abutment design, but was unable to find it, as all the

text-books dealt solely with the arch on the assumption that the abutments were immovable and said nothing about abutment design, taking it for granted a man could figure the abutments when he knew the thrust, the weight of the construction, and the bearing power of the soil.

To design an arch, however, in the careful, conscientious way it should really be designed,—that is, in the way it should be designed in case the designer expected to be called into court to act as an expert witness,—is a piece of work that cannot properly be completed by the usual methods in less than one week. First the crown thickness must be assumed and then the general form of the arch; finally, the approximate thickness of the arch ring from the crown to the abutment. This done, the dead load created by the fill and pavement must be found, and then assumptions made for different systems of loading. With the data found new thicknesses of arch ring are taken and the work done a second time. Skillful guessing, only possible by practice in this work, enables a designer to save some of the labor involved, but the man who does such work only occasionally is apt to stop with the first effort, or abandon the work in favor of an empirical formula and figure enough steel to make himself feel safe.

The method proposed by the author, and so well presented in his paper, lessens the labor by fully one-half, for the method of loading is immaterial. In the first two paragraphs of his paper the advantages of the ellipse of elasticity are set forth concisely and I cannot improve upon his statement. For comparison I took two arches, worked out in standard text-books, and went through all the work there given. Then this method of the ellipse of elasticity was used and the comparison was remarkably favorable. This method of comparing the usual methods with this proposed method is a good one to follow.

The author deserves the thanks of all concrete engineers for the paper he has presented this evening.

Mr. Janni: My design is perfectly independent of any hypothesis of loading. You can start your design as you wish and on those lines you put your load.

I wish to state that this method is not mine at all. What I did was to collect what great men have done in mathematics; that is all.

President Reichmann: When I started in the engineering profession, if the word arch was mentioned, almost every engineer was frightened. Little cantilever spans were generally used, and the arch was not used, practically speaking. But I am glad to see that in the last ten or fifteen years the arch has been introduced and we have been working on more scientific and more artistic lines, and it so happens that the artistic and the economical work out hand in hand. That is to say, it is not only more economical but also

more artistic to form an arch than it is any other span in many cases.

I am very glad that this subject has been brought before the Society, because it is something with which all engineers should be thoroughly conversant. We ought to have some short methods of arch design.

When I was with a railroad company some years ago, we used to build masonry arches, but we really never gave the subject any scientific treatment, simply figuring the arches according to Trautwine. But since the introduction of reinforced concrete, the arch has been given more scientific study for the so-called reinforced concrete arches. Of course, we have always had to give the subject of steel arches scientific treatment, but very few of them have been built. In recent years, however, we have been building more steel arches as well as the concrete arches, and they are not only much more handsome, but much cheaper.

Mr. Janni: You will notice that the first part of this paper deals only with the dead load, and the designer who is familiar with this, after only a half day's work knows perfectly well from those diagrams that his bridge is all right. In the masonry arch the live load is very small in comparison with the dead load, so the first part of this design is usually sufficient. I would not design for the live load on a highway bridge, but would for the live load on a railway bridge. With the railway bridge, the form of arch and the live load are important factors, but the highway bridge is a more simple structure. When we know we can build arches scientifically with only one day's work in the designing department, I think it is worth while to undertake it.

O. H. Basquin, M. W. S. E.: I am very glad that this paper has been presented and that this method of designing arches has been called to our attention. I understand Mr. Janni is proposing to draft a supplement that contains a demonstration of this method of doing the work, following the method that he has given here orally this evening. I think that will be a very valuable contribution to the literature in English on this subject.

Mr. Stern: I agree with Professor Basquin that if the author will send in, for publication with this paper in our *Journal*, a demonstration of this method of doing the work, it will make the paper that much more valuable. I also agree with Professor Basquin that this paper is a valuable contribution to engineering literature.

We are not all going into this subject as deeply as we might at this time, but we can assure the author that when one has an arch to build he will go through the paper thoroughly.

R. G. Rosenbach, M. W. S. E. (by letter): In line with the discussion of the paper on the design of an arch system by the method of the ellipse of elasticity, as presented by Mr. Janni, it may be of interest to some members of the *Western Society of Engineers* to compare the methods employed by Mr. Janni with those now com-

monly used in Germany for designing continuous arches. The following is a translation from the German, and the method which is based on the principles of the theory of elasticity has been used since 1906 in preference to the older methods, and extensive tests conducted by the *Austrian Society of Engineers and Architects* have demonstrated the soundness of this method and the principles involved. Discussions of this subject in its original form will be found in the *Schweizer Bauzeitung*, 1906, No. 7 and 8 and also in the *Beton Kalender*, 1909, II. pp. 209-215.

Assuming that we have to deal with a symmetrical arch AB (Fig. 1), let us suppose that the left pier or abutment at A has been removed; we will then have a cantilever beam fixed at the point B . If there is to be no change or distortion of the distribution of the strain in the arch, then we must apply the reaction R to the cross-section of the impost (skewback) A ; R must be equal to the reaction applied at A before the removal of the abutment. From the condition, that with unalterably fixed abutments there shall be no displacement of the cross-section of the impost A (neither in a horizontal nor in a vertical plane, nor shall there be a rotating distortion), three equations can be derived from which, by elimination, the vertical components of R , as well as the moments of R in regard to A , can be calculated for any certain condition of loading.

These equations can be derived more readily and the labor of elimination can be entirely omitted if at a certain point O (Fig. 1), this point O to be assumed to be in a rigid connection with the cross-section of the impost (skewback) A , the impost reaction R is applied twice and acting in opposite directions. Thus it will be possible to resolve the force R into two components V and H , and the other force R can be combined with the actual impost or (skewback) pressure (Kaempferdruck) into a couple about the moment $M = Rr$ and we obtain at the point O (Fig. 1a) three statically undetermined reactions H , V , and M . (The point O is always to be assumed to be in rigid connection with the lefthand cross-section of the impost.) If there is to be no displacement of this cross-section, then the point O is also to remain absolutely fixed, and there shall be no rotating movement of the impost cross-section about the point O . Any displacements of the impost cross-sections are conditioned by the change of form of every elementary portion of the arch. There is acting upon each section x of the arch, a bending moment M_x , a normal force N_x , and a cross-force Q_x . The latter force Q_x may be entirely disregarded in arch design, on account of the exceedingly small effect it has upon the change of form or shape in an arch. With reference to Fig. 1a, and its indicated system of coördinates, the following equations are developed:

1. Displacement of the point O with respect to the axis x .

The enlargement of the span due to the change in the form of an elementary portion of the arch is $dl = dr \cdot y - 1 \, ds \cdot \cos d$,

therefore for the entire arch, and considering a temperature increase of t° ,

$$O = \int \frac{M_x}{E I} ds \cdot y - \int \frac{N_x ds}{E F} \cos a_1 + e t, l$$

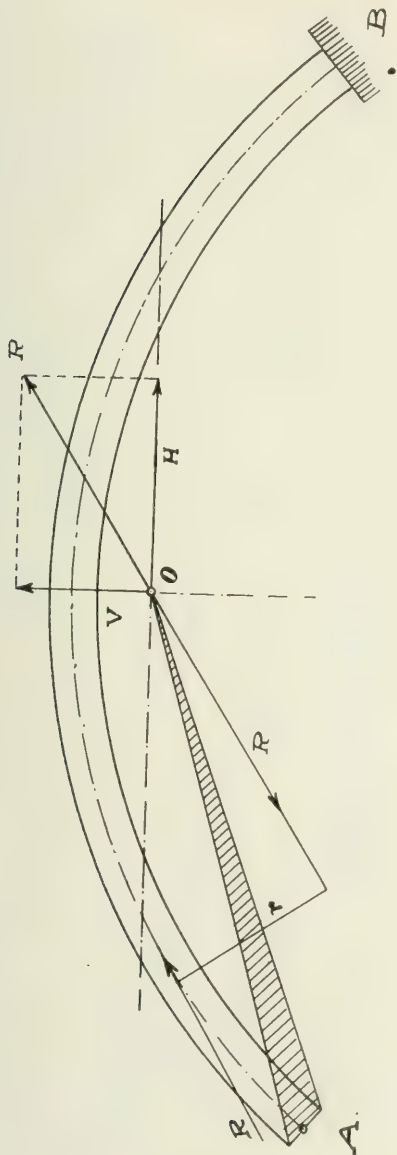


Fig. 1

e = coefficient of expansion.

I = moment of inertia.

F = area of cross-section of arch at point considered.

E = coefficient of elasticity (Kg. per sq. centimeter).

2. Displacement of the point O with respect to the axis y .

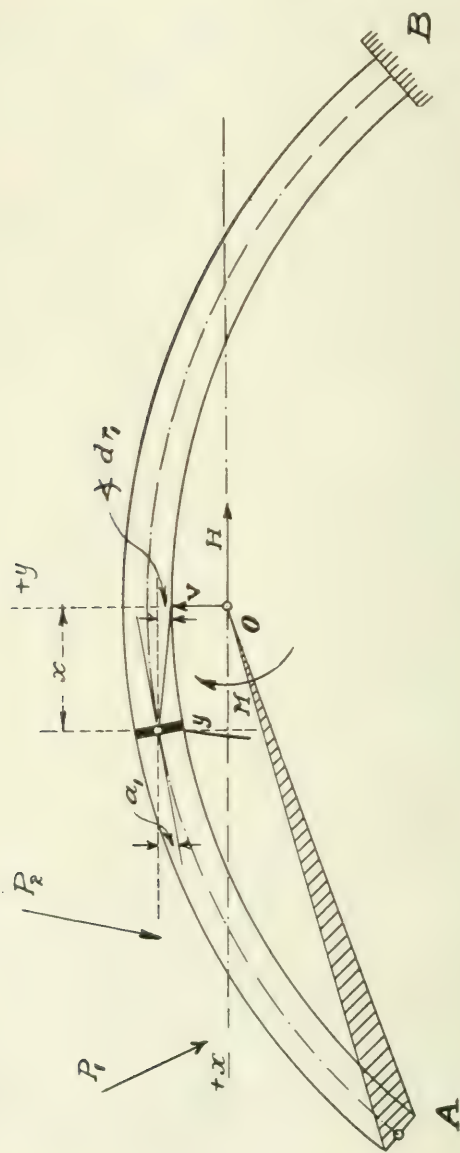


Fig. 1a

$$o = \int \frac{M_x}{E I} \cdot ds \cdot x + \int \frac{N_x \cdot ds}{E \cdot F} \cdot \sin a_1$$

3. Turning of the cross-section of the impost (skewback) about the point O .

$$o = \int \frac{M_x}{E I} \cdot ds.$$

Designating by M_o the moment of outside acting force P to the left of the section x , in regard to its center of gravity or the bending moment acting upon the assumed cantilever beam fixed at the right, we obtain the following expression for M_x

$$M_x = M_o + M - H \cdot y - V \cdot x.$$

$N_x \cos a$ can be considered as being equal to the horizontal thrust without any practical error, because the influence of normal forces are slight upon arches with considerable rise, and become important only with arches having extremely low rises.

Insert the values for M_x and $N_x \cos a$ in the above three equations, and select your positions for the system of coördinates about the point O so that

$$\int \frac{x \cdot ds}{I} = o; \quad \int \frac{y \cdot ds}{I} = o; \quad \int \frac{x \cdot y \cdot ds}{I} = o; \text{ we will then obtain}$$

$$H = \frac{\int \frac{M_o \cdot y}{I} \cdot ds + E \cdot a_1 \cdot t \cdot l}{\int \frac{y^2 \cdot ds}{I} + \int \frac{ds}{F}} = \frac{\int M_o \cdot d w \cdot y \cdot E \cdot a_1 \cdot t \cdot l}{\int d w \cdot y^2 + \int \frac{ds}{F}}$$

$$V = - \frac{\int \frac{M_o \cdot ds}{I} \cdot x}{\int \frac{x^2 \cdot ds}{I}} = - \frac{\int M_o \cdot d w \cdot x}{\int d w \cdot x^2}$$

$$M = - \frac{\int \frac{M_o \cdot ds}{I}}{\int \frac{ds}{I}} = - \frac{\int M_o \cdot d w}{\int d w}.$$

If we assume that the neutral axis of the arch is loaded with (elastic) weights, $d w = \frac{ds}{I}$, then the system of coördinates is to be selected as follows:

That the kernelpoint O shall coincide with the center of gravity of the arch loaded with weights $d w$;

2. That the axis of x and y shall lie in such manner that the centrifugal moment of the loads $d w$ becomes 0. In the assumed symmetrical arch the latter supposition has already become a fact when the axis y happens to coincide with the symmetrical axis, and the axis x is at right angles to y .

If we did not have to deal with variable traffic loads but only with a few predetermined factors of loading, then the formulae given above may suffice for making the necessary calculations. The integrals cannot be solved for all possible forms of arches and are to be approximately determined. For such purposes, divide the arch into an even number of equal parts, solve the integrals for the different parts, and add the results by Simpson's method. Or, divide the arch into any number of parts of lengths s , whereby the points of action of the concentrated loads coincide with the center

points of these parts, calculate the loads $w = \frac{s}{I}$ for the centers of these parts, and add the results

$$M_o. w. y; M_o. w. x; w. y^2, w. x^2$$

and so on, where all values refer to the centers of these separate parts of the arch.

Designating the values $w. y$ by w_y ; $w. x$ by w_x , we will then obtain the following equations:

$$H = \frac{\sum M_o. w_y}{\sum y. w_y + \sum \frac{s}{F}}; V = \frac{\sum M_o. w_x}{\sum x. w_x}; M = - \frac{\sum M_o. w}{\sum w},$$

It is assumed that the integrals are solved by the second method given above.

Attempting to ascertain the influence lines of the values H , V , and M , in cases of vertically acting loads, we have only to consider a single load $P = 1$ with the abscissa a at the arch (Fig. 2).

Then we will have, for all cross-sections of the arch for which $x > r$, $M_o = 0$

$x < a$, $M_o = -1. (a-x)$; therefore for such cases of loading we will have the summation

$$\sum M_o. w_y = - \sum_a^{l/2} w_y. (a-x)$$

$$\sum M_o. w_x = - \sum_a^{l/2} w_x. (a-x)$$

$$\sum M_o. w = - \sum_a^{l/2} w. (a-x),$$

that is, the sums are for the single weight $P = 1$ equal to the

elastic moment of the weights w_y , w_x , w , to the right of the point of action in regard to the line of action of the load.

If it is desired to obtain all influence lines completely, then it will be necessary to assign to the weight $P = 1$ a number of points of action, starting from the right and going toward the left. These points of action should preferably coincide with the centers of gravity of the parts S into which the arch will be divided, then calculate the moments of all elastic weights w_y , w_x , w , to the right from the point of action in regard to same.

The influence ordinates are then obtained when these moments are divided by the sum of the denominators of the values for H , V , and M .

Besides the purely mathematical method of procedure, there is also the possibility of a graphical solution. The graphical solution for the center of gravity O of the elastic weights requires no description as it is fully explained in Fig. 2 by the force polygon 1 and the cord polygon 1'.

Therefore we can represent all values which may be considered as static moments by means of cord polygons.

Denominator of H or $\Sigma_y w_y$. In order to find the static moments of the weights w_y with respect to the axis x , we will draw the force polygon 2, using any convenient pole distance h_y ; the corresponding cord polygon for horizontally acting weight w_y takes the form as illustrated by a in Fig. 2.

If the distance between the two starting points is designated by n_y , then we will have, on account of the last two sides being perpendicular to each other, $\Sigma_y w_y = w_y \cdot h_y$; to which we will add

the value of $\Sigma \frac{s}{F}$ which is obtained by means of calculations.

Denominator of V or $\Sigma x \cdot w_y$. For ascertaining the summation of the static moments of the weights w_x with respect to the axis y , the force polygon 3 in Fig. 2 is drawn, having a pole distance h_x ; the corresponding cord polygon is illustrated in c (Fig. 2) and it follows with $p q = n_x$

$$\Sigma x \cdot w_x = n_x \cdot h_x. —$$

Numerator of H or $\Sigma M_o \cdot w_y = — \Sigma w_y (a—x)$ for a single load $P = 1$. Here we draw the force polygon 4 with the pole distance h_y and the corresponding cord polygon b (Fig. 2). Then the moments of all weights w_y in regard to the load $P = 1$ is represented by the ordinate b directly under P multiplied by h_y , and the horizontal thrust becomes

$$H = \frac{b \cdot h_y}{n_y \cdot h_y + \Sigma \frac{s}{F}} = \frac{b}{n_y + \frac{l}{h_y} \frac{s}{F}}$$

Adding to the distance n_y the value of $\frac{l}{h_y} \sum \frac{s}{F}$, which is ob-

tained by calculation, representing the influence of the change of form of the arch due to normal forces, then we will obtain the numerator of the last expression for H , or we may consider the lastly drawn cord polygon as the influence lines of the horizontal thrust H , whereby the unit of measurements of the ordinates b is

represented by the distance $n_y + \frac{l}{h_y} \sum \frac{s}{F}$; n_y is also to be considered

a length, also $\frac{l}{h_y} \sum \frac{s}{F}$.

Numerator of V or $\sum M_o w_x = - \sum w_x (a-x)$ for a single load $P = 1$.

From the cord polygon c in Fig. 2 can be obtained the moment of all weights w_x in regard to the line of action of the load $P = 1$ the same as the ordinate b underneath the load P , multiplied by h_y ; also

$$V = \frac{b \cdot h_x}{n_x h_x} = \frac{b}{n_x};$$

or the cord polygon may be considered as influence lines for V , where the unit of measurement of the ordinates would be the distance n_x .

Numerator of M or $-\sum M_o w = + \sum_a^{l/2} (a-x)$.

Here we draw the force polygon 5 and the corresponding cord polygon d . The sum of the static moments of all elastic weights w to the right of the point of action in regard to the line of action of the load is then equal to the ordinate b falling between the last two sides of the polygon and multiplied by the pole distance h ; if $h = \sum w$ then

$$M = \frac{b \cdot \sum w}{\sum w} = b; \text{ that is, these ordinates measured as distances}$$

to a certain scale represent directly the influence of the load $P = 1$ to the moment M .

All influence lines of H , V , and M contain only positive values.

The influence lines of H , and V , as influence components of the skewback reaction R , are independent of the position of the point O , would therefore be maintained in the same condition if the statically unknown reactions in the skewback cross-section were taken as assumed values.

The calculations of the influence ordinates of the kernel-moments for a certain cross-section are done in accordance with the following equation:

$$M_k = M_o + M - H \cdot y_k - V \cdot x;$$

where M_o is the moment of the outside forces (here $P = 1$) to the

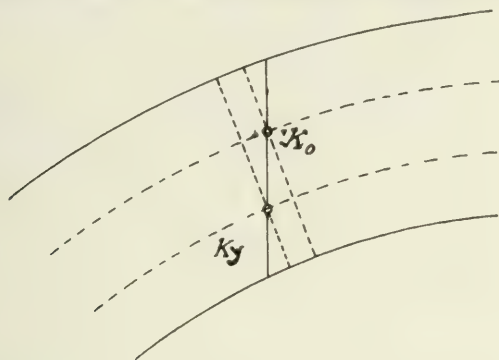


Fig. 3

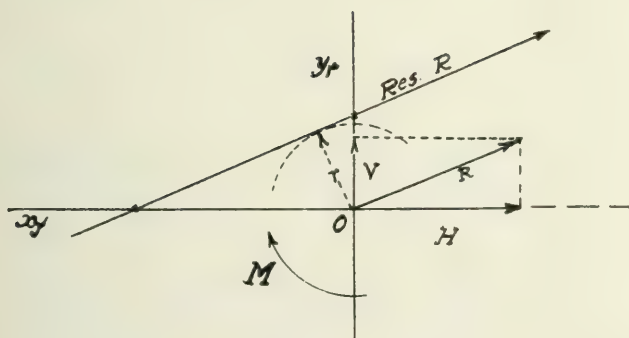


Fig. 4.

left of the section in regard to same. The selection of vertical cross-sections (Fig. 3) assists in this procedure inasmuch as M_o and $V \cdot x$ will then be of the same character and magnitude for the upper and lower kernelpoints.

For each kernelpoint, or for each section respectively, we will obtain a table for the determination of the influence ordinates M_k , by assuming all positions for the load $P = 1$ from o to l .

The values of M , H , and V are to be taken from the respective influence lines.

The live loads for the centers of the elements of the arch are to be assumed.

For any system of loading the lines of support may also be graphically represented.

From the influence lines or from the just calculated values, we obtain H , V , and M ; from which H and V are combined to obtain the resultant R ;

$$R = \sqrt{H^2 + V^2};$$

The distance r of the resultant from the point O is derived

$$\text{from the equation } R \cdot r = M \text{ to } r = \frac{M}{R};$$

R is therefore tangent to a circle about the point O , having a radius r where the prefix of M designates whether the tangent is to be above or below the circle. The points of intersection of R to the axes are as shown in Fig. 4.

$$x_r = \frac{M}{V}$$

$$y_r = \frac{M}{H}$$

APPENDIX.

On the evening of the meeting at which the preceding pages were presented and discussed, a number of members requested that the underlying theorems be given, with full mathematical analyses. Accordingly, the following is here given as an appendix to the original paper.—Ed.

GRAPHICAL CONSTRUCTION OF STATICAL AND INERTIAL MOMENTS AND PRODUCTS OF INERTIA.

A few theorems of graphical statics, which are useful in giving a clear view of the connection of the following principles with the various polygons constructed in the course of the design of an arch, are here recalled for the convenience of the reader.

1—*Statical Moment*: Let F_1 , F_2 and F_3 (Fig. 1) be three parallel coplanar forces. To obtain the static moments of the three above forces with respect to a given axis x , construct the equilibrium polygon on F_1 , F_2 and F_3 , with respect to the polygon of forces 0, 1, 2, and 3, and the pole P . The segments $0'1'$, $1'2'$, and $2'3'$ are proportional to the *static moments* desired.

2—*Product of Inertia*. Let y be another given axis in the same

plane. Through the points of application P_1 , P_2 and P_3 , of the forces F_1 , F_2 and F_3 , draw lines parallel to y . Assume forces of the same magnitude as $O'1'$, $1'2'$, and $2'3'$, which are the static moments with respect to the axis x , but considered to lie respectively in these lines parallel to y , and construct on them the equilibrium polygon with respect to the polygon forces $O'1'$, $1'2'$, and $2'3'$, and the pole P' , as shown in Fig. 1, giving the segments $O''1''$, $1''2''$, and $2''3''$ on the line y , which are proportional to the products of inertia of the forces F_1 , F_2 , and F_3 with respect to the axes x and y . The following equation suffices to compute from that construction

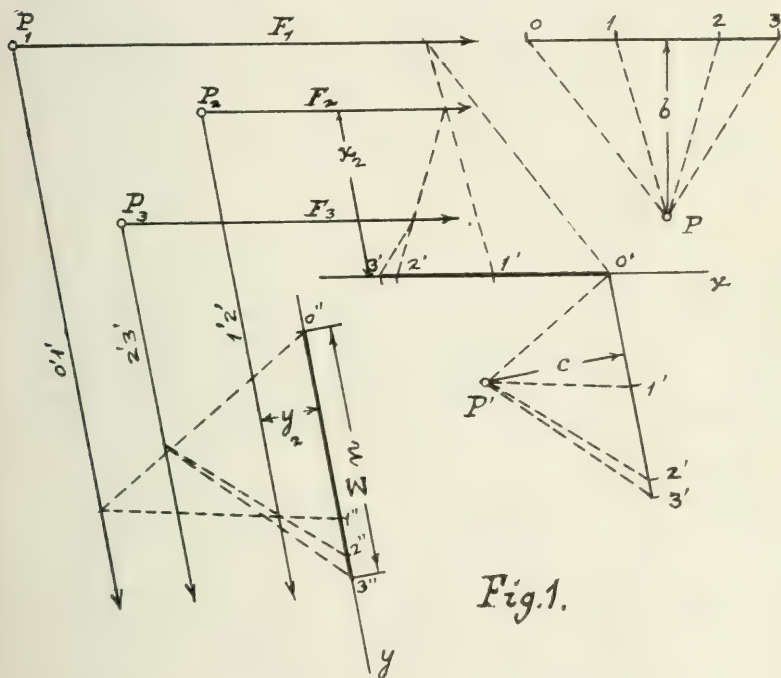


Fig. 1.

for any one of the given forces, say F_2 , the double moment called the *product of inertia*, with respect to the axes x and y :

$$F_2 \cdot x_2 \cdot y_2 = b \cdot c \cdot 1''2''$$

where b and c are the polar distances. Also, for the whole system:

$$\Sigma F \cdot x \cdot y = b \cdot c \cdot \Sigma n$$

where Σn (shown in the figure) is the sum of the intercepts on y of the last equilibrium polygon.

3—*Moment of Inertia*. If the axis y coincides with the axis x , the product of inertia assumes the special value called the *moment of inertia*.

Let F_1 , F_2 , and F_3 be three parallel coplanar forces. To ob-

tain the moment of inertia with respect to a given axis x , a procedure analogous to that of the preceding paragraph is followed, and is clearly shown in Fig. 2. The moment of inertia of the whole system is:

$$\Sigma F \cdot x^2 = b. c. \Sigma n$$

4—Center of Gravity of Static Moments. Any system of

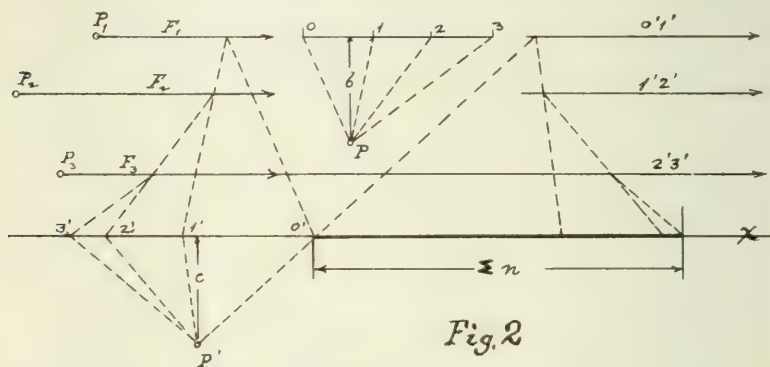


Fig. 2

forces such as F_1 , F_2 , and F_3 above has a center of gravity; so also, considering their static moments about any axis in their plane as a new system of forces, the latter also must have a center of gravity. This is called the center of gravity of the static moments, or, briefly, *the center relative to that axis*. Its position, of course, is dependent upon that of the axis of moments. To locate this

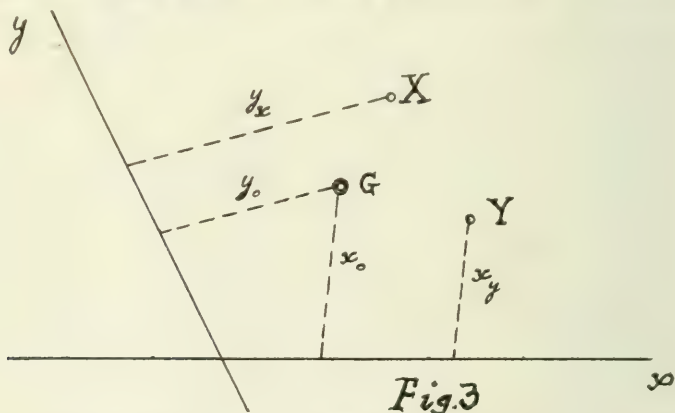


Fig. 3

center relative to the axis, lay off lines representing to scale the magnitudes of the static moments considered as forces, and proceed precisely as in finding the center of gravity of a plane system of forces. Below are given several important properties of such centers.

5—Conjugate Axes. In Fig. 3 let G be the center of gravity of

a system of forces, X the center relative to the axis x , and Y the center relative to the axis y (that is, X is the center of gravity of the static moments of the forces about the axis x , Y those about y).

Also let the distances from G , X and Y to the axes be computed in any assumed direction; then, since the sum of the static moments of the forces of the system with respect to the axis x equals the moment of the resultant with respect to the same axis:

$$\Sigma F \cdot x = x_0 \cdot \Sigma F$$

Then, as explained in the preceding paragraph, if the individual products $F \cdot x$ are regarded as forces, and their static moments with respect to y are found, the following equation may be written:

$$\Sigma F \cdot x \cdot y = y_x \cdot \Sigma F \cdot x$$

Substituting further the value for $\Sigma F \cdot x$, is obtained:

$$\Sigma F \cdot x \cdot y = y_x \cdot x_0 \cdot \Sigma F$$

If the order of computing the static moments were reversed, we should have:

$$\Sigma F \cdot y \cdot x = x_y \cdot y_0 \cdot \Sigma F$$

Combining the last two equations:

$$y_x \cdot x_0 = x_y \cdot y_0$$

If neither x nor y pass through G , that is, neither x_0 nor y_0 be zero, then, to satisfy the last equation, should y_x be zero, then also will x_y be equal to zero. Hence: *If the center relative to an axis falls upon another axis, the center relative to latter will fall upon the first.*

Again, if an axis y pass through a center X , then its relative center Y will fall on the axis x , of which X is the relative center. Therefore, any axis passing through the given point X , the relative center of the axis x , will have its relative center lying on x . Hence, to each line of the set of lines in the plane considered passing through X (pencil of rays in the language of projective geometry), will correspond a definite point of a set of points (range) upon the axis x of which X is the relative center. There is, therefore, a "projective correspondence" between axis and center.

Two axes, so situated that each passes through the center (pole) of the other, are called *conjugated axes*.

Either of the equations:

$$\Sigma F \cdot x \cdot y = y_x \cdot x_0 \cdot \Sigma F$$

or:

$$\Sigma F \cdot y \cdot x = x_y \cdot y_0 \cdot \Sigma F$$

may, in view of the preceding, be thus stated:

The product of inertia of a plane system of forces with respect to two conjugated axes is zero, and the converse.

6—Applying this reasoning to the special case of the product of inertia, which is called the moment of inertia, the latter with

respect to an axis x may be found, and, calling x_x the distance from the center X to the axis x , there is derived the equation:

$$\sum F \cdot x^2 = x_x \cdot x_o \cdot \sum F$$

By transposition:

$$x_x = \frac{\sum F \cdot x^2}{x_o \cdot \sum F}$$

The value of x_x , if the axis x pass through the center of gravity G (when $x_o = 0$) is ∞ which means that:

The center relative to an axis passing through the center of gravity falls upon the line lying at ∞ .

In this case, to the pencil having its center in the center of gravity G will correspond a range of points lying upon the line at ∞ , so that it may be said that this line at ∞ is the axis of the center of gravity of the system.

THEORY OF THE ELLIPSE OF ELASTICITY METHOD FOR THE GRAPHICAL DESIGN OF ARCHES AND OTHER ELASTIC STRUCTURES.

7—In the following pages the mathematical theory of the ellipse of elasticity method of arch design is presented.

The essential advantage of the ellipse of elasticity theory is that by its use may be collected under one concept, independent of the forces which may act thereon, all the properties of an elastic structure required for its complete investigation, for any assumed system of loading forces which may later be assigned. This eliminates much cut-and-try labor, and permits the development of a very flexible working method of design.

SYNOPSIS OF THE FUNDAMENTAL PRINCIPLES.

It will be shown:

a). That, considering the displacement of the terminal point A of an elastic system by a force F_1 as a rotation about some instantaneous center O_1 , and of F_2 similarly about O_2 , the center of rotation due to the simultaneous action of F_1 and F_2 will lie on a straight line joining O_1 and O_2 , and that, as a consequence;

b). If A is acted upon by a force in any direction, but passing through a fixed point P , the center of rotation will travel on a straight line;

c). That if F_3 be a force through P and O_1 (the center of rotation for a force F_1 through P), then will F_1 pass through O_3 (the center of rotation of F_3);

d). Also, that if a force whose line of action lies in the line $O_1 O_3$ acts upon A , the center of rotation of the resultant displacement of A will be P , such system of three forces and their centers of rotation uniquely determining a polar system to which all forces and centers of the plane belong;

e). That the polar system so determined has no auxiliary

conic, but that points symmetrical with respect to the center of the system, together with the forces, determine another polar system which has an ellipse as its auxiliary conic, this being what is known as the *ellipse of elasticity* of the system;

f). That on decomposing any force, F_1 , acting upon a terminal point A , into an equal and parallel one through G , the center of the ellipse, and another, infinitely small and with its line of action at infinity (equivalent to a couple), the first component causes a displacement in a straight line perpendicular to the diameter conjugate to the diameter upon which the force lies, and the moment M , due to the couple, causes a rotation about the center G of the system (center of the ellipse), through an angle ϕ , where $\phi = G \cdot M$; the constant G being called the *elastic weight* of the elastic system;

g). Furthermore, that, since $M = F \cdot r$, so that $\phi = G \cdot r \cdot F$, the angle of rotation of the point A about the center of the system is equal to the product of the force F and the statical moment of the elastic weight G with respect to the line of action of F ;

h). Also, that, since the displacement δ of the point A in any direction Av is equal to $\phi \cdot d$, where d is the perpendicular distance from the center of rotation to the line Av , $\delta = F \cdot r \cdot d \cdot G$; that is, the displacement is equal to the product of the force F by the product of inertia of the elastic weight G with respect to the line of action of F , and the direction line Av , along which the displacement is computed, and if the direction line coincide with the action line of F , this product of inertia becomes the moment of inertia.

These principles form the basis of the whole theory. It will be seen that the treatment of any displacement is reduced to finding the appropriate functions of the elastic weights, and later multiplying these by the acting forces F .

DEMONSTRATIONS OF THE FUNDAMENTAL PRINCIPLES.

8—*Composition of Rotations*: Let P , Fig. 4, be a point of an elastic system, which, by any means is infinitesimally displaced to P' . The displacement PP' may be regarded as a rotation about an instantaneous center, say O_1 , through an angle ϕ_1 . Let there be another displacement starting from the same point P , through an angle ϕ_2 , about a center O_2 .

Join O_1 and O_2 by a straight line and erect $AP = y$, perpendicular to $O_1 O_2$. Decompose PP' into $P P_{y1}$, perpendicular, and $P P_{x1}$ parallel to $O_1 O_2$. Then the triangles $AP O_1$ and $PP' P_{x1}$ are similar, as their sides are perpendicular. Also, since the angles of rotation are very small $\tan. \phi = \phi$.

Hence:

$$\frac{PP'}{PP_{x1}} = \frac{PO_1}{PA}$$

but:

$$PP' = PO_1 \cdot \tan. \phi_1 = PO_1 \cdot \phi_1, \text{ and } \frac{PO_1}{PP_{x_1}} \phi_1 = \frac{PO_1}{y}$$

Therefore:

$$PP_{x_1} = \phi_1 \cdot y$$

Also:

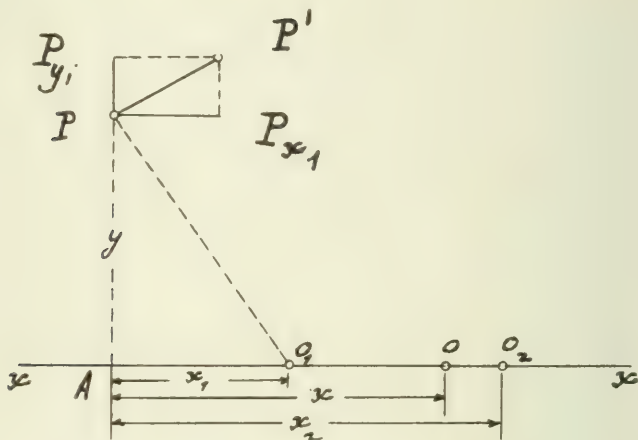


Fig. 4

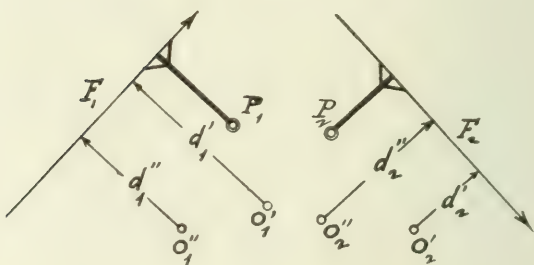


Fig. 5

$$\frac{PP'}{PP_{y_1}} = \frac{PO_1}{AO_1} \cdot \frac{\phi_1}{PP_{y_1}} = \frac{1}{x_1}$$

Therefore:

$$P P_{y_1} = \phi_1 \cdot x_1$$

Similarly for a rotation about O_2 from P :

$$P P_{x_2} = \phi_2 \cdot y$$

$$P P_{y_2} = \phi_2 \cdot x_2$$

The sums of the components of these displacements will be:

$$P P_y = P P_{y_1} + P P_{y_2} = \phi_1 \cdot x_1 + \phi_2 \cdot x_2$$

$$P P_x = P P_{x_1} + P P_{x_2} = \phi_1 \cdot y + \phi_2 \cdot y = (\phi_1 + \phi_2) y$$

Let O be the center of gravity of forces proportionate to ϕ_1 and ϕ_2 applied respectively at O_1 and O_2 . If the point P rotates about the center O , through an angle $\phi = \phi_1 + \phi_2$, the components of this displacement, according to the same direction as above, will be given, as proved for the first rotation, by:

$$P_y = \phi \cdot x = \phi_1 \cdot x_1 + \phi_2 \cdot x_2$$

$$P_x = \phi \cdot y = (\phi_1 + \phi_2) y$$

These values are identical with those above found for the sums of the components of the two displacements, therefore:

The resultant rotation of two rotations of a point P about the centers O_1 and O_2 respectively through the angles ϕ_1 and ϕ_2 , is a rotation through an angle $\phi = \phi_1 + \phi_2$ about the center of gravity O of forces proportionate to ϕ_1 and ϕ_2 , applied respectively at centers O_1 and O_2 , as outlined in paragraph 7, a).

9—*Principle of Reciprocity.* Let P_1 and P_2 in Fig. 5 be two points belonging to the same plane elastic system. A force F_1 , rigidly connected with P_1 , acts upon the system, increasing from the value zero to its maximum value F_1 .

The effect upon P_1 is to rotate the latter through an angle ϕ_1' about an instantaneous center of rotation O_1' . When F_1 reaches its maximum value, a second force F_2 , rigidly connected with P_2 , begins to act with an initial value zero, increasing to its maximum F_2 . A corresponding rotation through an angle ϕ_2'' about some center O_2'' results.

The rotation of P_1 caused by F_1 (constant at the value F_1 , and still acting as described above), during this interval, will be about some center O_1'' , and will extend through some angle ϕ_1'' . When F_2 has reached its final value F_2 the virtual work done by both forces upon the system will be:

$$\frac{1}{2} \cdot F_1 \cdot \phi_1' \cdot d_1' + \frac{1}{2} \cdot F_2 \cdot \phi_2'' \cdot d_2'' + F_1 \cdot \phi_1'' \cdot d_1''$$

If the order of action of F_1 and F_2 upon the system be reversed, and if the angle of rotation of P_2 about the new center O_2' during the action of F_1 be ϕ_2' , the virtual work will be:

$$\frac{1}{2} \cdot F_2 \cdot \phi_2'' \cdot d_2'' + \frac{1}{2} \cdot F_1 \cdot \phi_1' \cdot d_1' + F_2 \cdot \phi_2' \cdot d_2'$$

But as the order of action of these two forces is immaterial, so far as the final and initial positions of the elastic system are con-

ter of rotation corresponding to the force F_1 through P), then the force F_2 will not have a rotating effect upon the system during the action of the force F_1 , since it passes through O_1 , the center of rotation due to F_1 ; by the principle of reciprocity, therefore, the force F_1 will pass through O_2 , center of rotation due to F_2 .

11—*Polar systems determined by forces and centers of rotation:* Now in the language of projective geometry (see: L. Cremona, *Elements of Projective Geometry*, translated by Chas. Leudesdorf, 1885, Clarendon Press, Oxford), the points P , O_1 and O_2 , together with the straight lines p , F_1 and F_2 , constitute three pairs of elements which correspond to each other in a double manner, *i. e.*, to the center P corresponds the line p , and to the line p corresponds the center P , and similarly with the two remaining pairs.

This graphical relation between a straight line (force) and a point (center of rotation) is true also for all lines and points belonging to the same plane, since the lines of action of the forces assumed were subject to no restriction as to position; they all, therefore, belong to the same polar system, which is uniquely determined by the three pairs of conjugate elements, P , p ; O_1 , F_1 and O_2 , F_2 . For this system, however, the auxiliary conic is imaginary (since there is no point lying on its own polar, as the center of rotation cannot lie on the line of action of the force, see Cremona).

However, taking the straight lines p , F_1 and F_2 , and the points symmetrical with P , O_1 and O_2 , with respect to the center of the system just noted, they together determine another polar system whose auxiliary conic is real and is an ellipse, and with respect to which, forces and the corresponding centers of rotation are to be regarded as polars and antipoles, respectively.

This ellipse is called *the ellipse of elasticity* of the elastic system under consideration.

12—*Construction of the antipoles of the ellipse:* Let p be, Fig. 7, a polar with respect to an ellipse whose axes are AB and CD . Let us lay off on OC the segment $OB' = OB$, similarly the segment $OC' = OC$. Join E with B' and F with C' ; then through B' draw $B'P_x$ normal to EB' , and similarly through C' so obtaining $C'P_y$.

The point P , having OP_x and OP_y as its coördinates, will be the antipole of p with respect to the given ellipse.

The pole of p will be the point P' , which is symmetrical with P with respect to the center O .

13—Let a force F_1 , Fig. 6, be decomposed into two others, one equal and parallel to F_1 , passing through G , the center of the ellipse described, the other infinitely small, with its line of action at infinity (corresponding to a couple).

The first component will cause a rotation about the corresponding antipole of the diameter upon which the component lies. But by paragraphs 5 and 6 the pole and the antipole of a diameter lie at infinity on the conjugate diameter, therefore this component

causes a rotation about a point at infinity, that is, a displacement in a straight line perpendicular to the conjugate diameter.

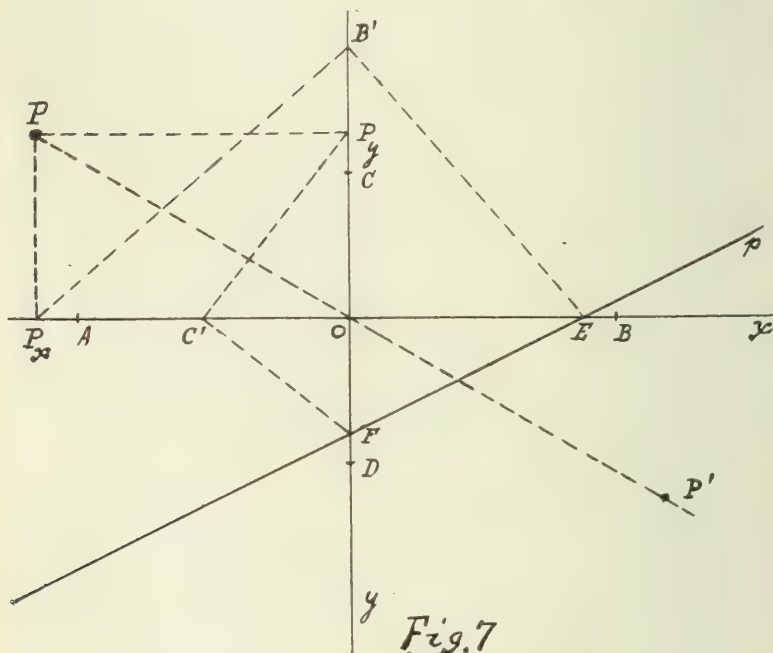
14—The second component (which is equivalent to a couple), whose moment is M , where

$$M = F \cdot r$$

will cause a rotation through an angle ϕ about the center of the ellipse (since the center is the pole and the antipole of a line at infinity), ϕ being proportional to M , whence:

$$\phi = G \cdot M$$

The constant G is called the *elastic weight* of a given elastic system.



15—Considering the elastic weight G as applied at the center of the ellipse and substituting for M its value,

$$\phi = F \cdot r \cdot G$$

Expressed formally, this means that:

A terminal point A of a plane elastic system acted upon by, a force F rigidly connected with it, will rotate about the antipole (with respect to the ellipse of elasticity of the system) of the line of action of F, the angle of rotation being equal to the product of F by the statical moment with respect to the line of action of F of the elastic weight G.

16—The displacement δ of the point A in a direction Av is equal to the product of the angle of rotation ϕ by the distance d between the center of rotation and the direction line Av . (See paragraph 8.) Whence:

$$\delta = F.r.d.G$$

That is:

The displacement δ of a point A in a direction Av , due to a force F is equal to the product of the force by the product of inertia of the elastic weight taken with respect to the lines F and Av .

If the line Av coincides with the line of action of F , the product of inertia becomes the moment of inertia taken with respect to the line Av .

17—*Calculation of elastic weights:* Let AB , Fig. 8, be a fractional part or element of an elastic system acted upon by the moment M .

(These elements are to be taken small enough to be considered of constant cross-section, and are to be regarded as fixed at one end and free at the other.) The virtual work done by this moment will be:

$$L = M.\phi$$

where ϕ is the angle of rotation of the terminal section B with respect to the section A . From the theory of deflection:

$$\phi = \frac{M.l}{E.I}$$

Therefore:

$$L = M.\phi = M^2.G = \frac{M^2.l}{E.I}$$

substituting the value of ϕ given in paragraph 14. Hence:

$$G = \frac{l}{E.I}$$

which formula suffices for calculating the elastic weights.

18—*Calculation of minor axis of the ellipse of elasticity:* Let the element AB , Fig. 9, be stretched by a force N acting in the geometrical axis of AB at the face B . Its virtual work will be:

$$L = N.\Delta l = N.\frac{N.l}{E.A} = \frac{N^2.l}{E.I} \cdot \frac{I}{A} \text{ where: } A = \text{area of}$$

cross-section. Substituting the value of G given in paragraph 17:

$$L = N^2.G.\frac{I}{A}$$

ρ being the semi-axis of the ellipse of elasticity as shown in the figure, the displacement of the face B , in view of the principles given in paragraph 16, is: $N.G.\rho^2$; therefore:

$$L = N \cdot N \cdot G \cdot \rho^2$$

But as the virtual work is the same in both cases:

$$N^2 \cdot G \cdot \frac{L}{A} = N^2 \cdot G \cdot \rho^2$$

Therefore:

$$\rho = \sqrt{\frac{L}{A}}$$

which is the semi-axis of the ellipse of elasticity normal to the geometrical axis of the element AB .

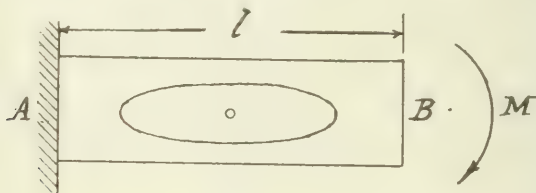


Fig. 8

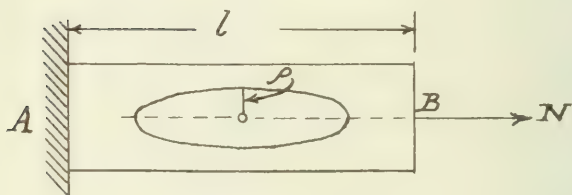


Fig. 9

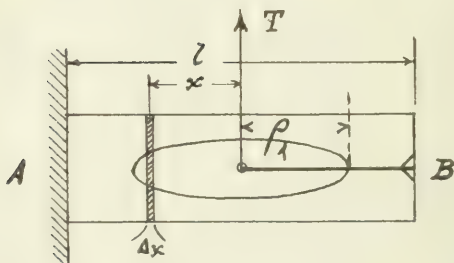


Fig. 10

19—*Calculation of the major axis of the ellipse of elasticity:* Let AB in Fig. 10 be the same element of the system considered above, and T , perpendicular to the axis, a force passing through the center of the ellipse, and rigidly connected with the face B . The virtual work becomes:

$$L = T. \delta$$

which, in the light of paragraph 16, becomes:

$$L = T. T. G. \rho_1^2$$

in which ρ_1 is the semi-axis shown in the figure.

Dividing the solid AB into elements Δx

$$M = T. x$$

where x is the distance between any one of these elements and the center of the ellipse. By the usual formula for virtual work:

$$L = \int \frac{M^2. dx}{E. I} + \int x \frac{T^2. dx}{S. A}$$

Integrating between $-\frac{1}{2}l$ and $+\frac{1}{2}l$ this will become:

$$L = \frac{T^2. l^3}{12. E. I} + x \frac{T^2. l}{S. A} = T \frac{T. l}{E. I} \left(\frac{l^2}{12} + \frac{E}{S} x \rho^2 \right)$$

in which S is the modulus of elasticity in shear and x is a numerical constant, depending only upon the cross sectional shape.

From the equation:

$$L = T. T. G. \rho_1^2$$

$$\rho_1 = \sqrt{\frac{l^2}{12} + \frac{E}{S} x \rho^2}$$

If we assume $S = \infty$, as is always permissible in arch design, in other words, if we neglect shear, then the above formula becomes:

$$\rho_1 = l \sqrt{\frac{1}{12}}$$

which is the value of the semi-axis of the ellipse of elasticity along the geometrical axis of the solid.

20—*Elementary Applications:* In the design of an arch, one end is assumed free and the other fixed, the ellipse of elasticity with respect to the free end being determined. The elastic weight of each voussoir (calculated as explained in paragraph 17), considered as a force in accordance with the preceding principles, is applied at the center of gravity of the corresponding voussoir or element into which the arch is divided, and the ellipse of elasticity constructed by the same methods employed in graphical statics to find

the ellipse of inertia will be the ellipse of elasticity relative to the free end of the system. In other words, the ellipse of elasticity is simply the ellipse of inertia of the elastic weights.

21—Let AB in Fig. 11 be an elastic arch, with fixed end at B and free end at A , divided into an arbitrary number of voussoirs. Now let a force F , rigidly connected with the terminal point A , act upon the system. It will cause a rotation of the section A with respect to the section B , whose value will be:

$$\phi = F. r. \Sigma \frac{\Delta s}{E. I} = F. r. G \text{ (see par. 15);} \quad \checkmark$$

where $\Delta s = l =$ length of voussoir, and $\Sigma \frac{\Delta s}{E. I} =$ the sum of all the elastic weights, that is, the total elastic weight of the arch, G .

The rotation through the angle ϕ will be about D , the antipole of F with respect to the ellipse of elasticity of the whole arch (see paragraph 11).

22—The displacement δ of A along any given direction Ax , is, by paragraph 16:

$$\delta = F. r. d. G$$

where $d =$ distance from the direction line Ax to the center of rotation, or antipole D , and;

$r =$ distance from the center of the ellipse to the line of action of F .

23—When the force F , Fig. 12, passes through the center of gravity G of the system, by paragraph 6, the point A moves on the normal Aa to y , the conjugate diameter of the line of action of F , with respect to the ellipse. It is, therefore, only when a force F acts along an axis of the ellipse that the displacement of A is parallel to the line of action of the force (since the axes are the only conjugate diameters of the ellipse perpendicular to each other). The expression for δ , given above, becomes indeterminate since $d = \infty$, and $r = 0$. But the component of the displacement of A in the direction Ax is:

$$\delta = F. d. r. G$$

Where, $d =$ distance from the direction line Ax to the center of the ellipse, $r =$ distance from the line of action of F to the center of rotation, or antipole X of the direction line Ax . (See paragraph 5).

24—Hence, if F acts along Ax , Fig. 13, the displacement along this line itself is given by the product of the force F and the moment of inertia of the elastic system with respect to the line Ax ; but for paragraph 6 the expression of δ given in paragraph 22 remains unchanged, therefore:

$$\delta = F. r. d. G$$

APPLICATION TO A TRUSSED ARCH RIB.

25—The preceding principles will now be applicated to the case of a trussed arch rib, as this is simpler than the case of a solid

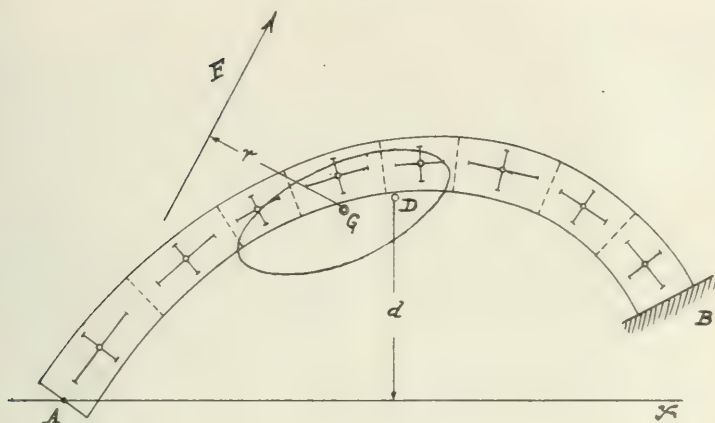


Fig 11

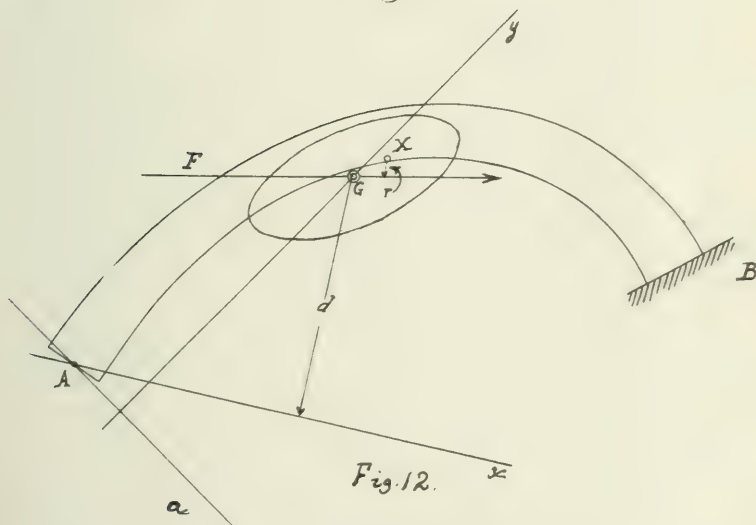


Fig. 12.

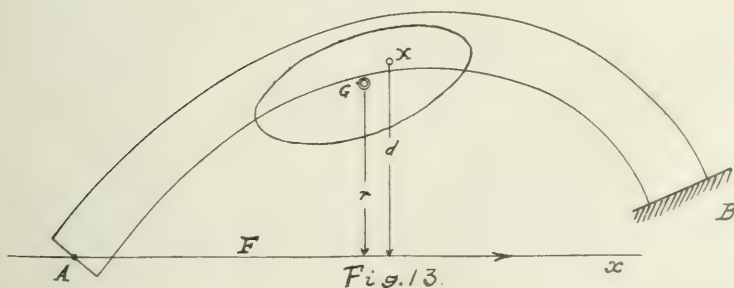


Fig. 13.

rib, and the extension of the general method to the solid arch depends upon this case. The treatment, however, will be incidental, and only those points of detail of interest for the development of the solid arch theory carried out in complete working detail.

Figure 14 represents an arch with fixed ends for which the ellipse of elasticity is to be drawn. Also, there are to be constructed five polygons (funicular polygons).

26—*Polygon p_1* : The elastic weights w (which for a trussed rib are different from the values previously derived in paragraph 17, since the basis there used does not here apply; this fact, however, having no importance as affecting the demonstration of the method itself), are treated as vertical forces applied at their respective poles 1, 2, 3, . . . 11. The eleven elastic weights $w_1, w_2, w_3, \dots, w_{11}$, are laid off on a vertical, and a pole P_1 is chosen whose distance from the vertical is equal to the length of the vertical, i. e., Σw . The funicular polygon p_1 corresponding to this pole and load line is then laid off to connect the verticals through the poles 1, 2, 3, . . . 11. The vertical y (resultant), through the intersection of the first and last sides of the polygon p_1 will, by ordinary graphics, contain the center of gravity of the system of the elastic weights. Furthermore, the sides of the polygon p_1 , produced, will determine on this vertical segments proportional to the static moments of the corresponding elastic weights with respect to this same vertical through the center of the system.

Drawing a vertical through any pole (the poles or centers of rotation of a truss are the joints), for example pole 4, polygon p_1 will cut it in two points; the segment η_0 , intercept between these points, is proportional to the static moment of all the elastic weights to the right of 4 with respect to this vertical.

27—*Polygon p_2* : By the methods of graphical statics determine the axis x conjugate with the axis y (see paragraph 5 for definition of conjugated axes). At the same time is determined G , the center of gravity of the system of elastic weights.* Again treating the elastic weights as forces applied at the points 1, 2, 3, . . . 11, as before, this time, however, parallel to the conjugate axis x , lay off the eleven elastic weights on a line parallel to x , assuming a pole P_2 on y for convenience, and connecting the lines through 1, 2, 3, . . . 11 parallel to x by the corresponding funicular polygon p_2 . The center of gravity of elastic weights acting in this direction lies on a line parallel to x through the intersection of the first and last sides of the polygon p_2 .

The intersection of this line with the line y gives again the center G of the system.

28—*Polygon p_3* : Taking a pole P_3 at an arbitrary distance λ_3 from the vertical resultant y described under polygon p_1 , and considering the statical moments with respect to this vertical as

*In Fig. 14 this construction has been made assuming any vertical axis y^1 and finding its relative pole Y .

vertical forces, applied to the same respective poles 1, 2, 3, . . . 11 (as indicated in paragraph 2 et seq.), construct the funicular polygon p_3 , connecting such forces acting in the lines of the verticals through these poles. Then the expression $\Sigma w \cdot \lambda_3 \cdot v$ will be the moment of inertia of the elastic weights with respect to the axis y , where v is the distance measured parallel to y between the first and last sides of polygon p_3 . This is shown by paragraph 3; the values Σw , λ_3 , and v here, corresponding respectively with b , c , and Σn of that paragraph.

29—*Polygon p_4* . Just as the sides of p_1 intercept on y segments proportional to the static moments with respect to y of the elastic weights, so do the sides of p_2 intercept on x segments proportional to the static moments with respect to the axis x of the elastic weights, when they act in the direction parallel to x . Treating such segments as forces parallel to x applied at the poles 1, 2, 3, . . . 11, previously used, assume a pole P_4 at a distance v (given under polygon p_3) from x , and construct the corresponding funicular polygon p_4 (to the right of the truss in the figure); this will make the moment of inertia of the elastic system with respect to the axis x equal to $\lambda_2 \cdot v \cdot n$. (see par. 3 where b , c , and Σn respectively correspond to λ_2 , v , and n) when n is the distance between the first and last sides of p_4 , measured parallel to x .

30—*Ellipse of Elasticity*. The quantities so far obtained admit of the drawing of tangents to the ellipse of elasticity of the system, parallel to the axes x and y . Their normal distances from x and y are:

$$\sqrt{\frac{\lambda_2 \cdot v \cdot n}{\Sigma w}}, \text{ and } \sqrt{\frac{\Sigma w \cdot \lambda_3 \cdot v}{\Sigma w}} = \sqrt{\lambda_3 \cdot v}$$

corresponding to the general formula:

$$\rho = \sqrt{\frac{\bar{I}}{A}} = \sqrt{\frac{\text{Moment of inertia of forces}}{\text{Sum of forces}}}$$

and if λ_2 is so taken that:

$$\frac{\lambda_2}{k} = \Sigma w$$

then:

$$\sqrt{\frac{\lambda_2 \cdot v \cdot n}{\Sigma w}} = \sqrt{\frac{k \cdot \lambda_2 \cdot v \cdot n}{\lambda_2}} = \sqrt{k \cdot v \cdot n}$$

From these conjugate diameters the ellipse may be drawn. This is not done in the figure, but the diameters are shown in heavy lines, since two conjugate diameters suffice for all purposes.

31—*Polygon p_5* . Polygon p_2 gives the static moments of the

elastic weights with respect to the axis x . Apply these eleven static moments, considered as forces, to the same poles 1, 2, 3, . . . 11, but this time acting vertically; lay them off on a vertical, and assume a pole P_5 , distant n (segment proportional to the moment of inertia of the whole system with respect to the axis x , see polygon p_4), from this vertical, and connect their lines of action by the funicular polygon p_5 . Its first and last sides coincide because the directions of x and y are conjugated (see par. 5) and the product of inertia with respect to the two axes must therefore be zero.

Polygon p_5 will intercept on a vertical through any pole, for example, pole 4, a segment η_2 proportional to the product of inertia of elastic weights to the right of pole 4. Its value is $\lambda_2 \cdot n \cdot \eta_2$ (see par. 2).

32—Assuming now a load 1 to be applied at any point, for example pole 4, and the left end of the arch free, the right end fixed, the force 1 will displace the free end of the arch and any point rigidly connected therewith, for example G . Such displacement may be conceived as composed of a rotation, a vertical displacement along y , and a displacement along x .

33—The rotation of G is equal to the force 1 multiplied by the sum of the static moments of all the elastic weights to the right of the line of action of the force 1 with respect to this line of action (see par. 15). If η_0 (polygon p_1) is the segment proportional to the static moment on this vertical, the rotation sought will be:

$$1. \Sigma w. \eta_0$$

34—The vertical displacement of G is equal to the product of the force 1 by the moment of inertia of all the elastic weights to the right of 4, with respect to the vertical through 4. If η_1 (polygon p_3) is the segment proportional to this moment of inertia, then, by paragraphs 16 and 28 its value is:

$$1. \Sigma w. \lambda_3. \eta_1$$

35—The displacement of G along x is given by the product of the force 1 and the product of inertia of the elastic weights at the right of 4 with respect to the line of action of the force 1, and to the axis x (paragraphs 16 and 31). Hence, if η_2 (polygon p_5) is the segment proportional to the product of inertia, the actual value of this product will be:

$$\lambda_2 \cdot n \cdot \eta_2$$

and the displacement will be:

$$1. \lambda_2 \cdot n \cdot \eta_2$$

REACTIONS.

36—To force the free end (left end of the truss) to return to its original position, will require the application of a reaction to the free end. The reaction, of course, will force back the point G rigidly connected with the free end of the arch, and may be con-

sidered as the resultant of a moment M about G , a vertical reaction A along y , and a reaction H along x .

37—The rotation of G due to the moment M is given by:

$$G. M$$

which is equivalent to:

$$\Sigma w. M$$

but the rotations of G , one due to the force 1 and the other due to the reaction moment M , must be the same, therefore:

$$\Sigma w. M = 1. \Sigma w. \eta_0$$

or:

$$M = 1. \eta_0$$

38—The vertical displacement of G due to the vertical reaction A is equal to the product of the force A and the moment of inertia of the whole elastic system with respect to the vertical through G , namely:

$$\Sigma w. \lambda_3. v$$

Then:

$$A. \Sigma w. \lambda_3. v$$

will be such displacement, and it must be equal to that previously found, or:

$$A. \Sigma w. \lambda_3. v = 1. \Sigma w. \lambda_3. \eta_1$$

Supposing that v is, to scale, the unit of force, then:

$$A = \eta_1$$

39—The displacement of G along x is given by the product of the force H and the moment of inertia of the elastic weights of the whole system with respect to the axis x , that is:

$$H. \lambda_2. v. n$$

Putting this equal to that previously found:

$$H. \lambda_2. v. n = 1. \lambda_2. n. \eta_2$$

Assuming again that v is the unit of force,

$$H = \eta_2$$

40—*Influence Lines.* It is therefore evident that the three polygons p_1 , p_3 and p_5 are the influence lines of the three quantities M , A and H .

41—*Position of Reactions.* The polygon p_3 permits finding the reactions at the fixed end also, if we refer this polygon to its side, at the left in the figure. It is then easy to find the values of the reactions (total reactions R_1 and R_r) at the left and right ends, the construction being shown in Fig. 14. (See also the table for Horizontal Thrust Polygon p_5).

To find the actual position of the two reactions with respect to the arch, the moment M of the force acting is given with respect to the center G , hence:

$$M = 1. \eta_0 = R_1. \delta$$

where δ is the lever arm of the moment, therefore:

$$\delta = \eta_0. \frac{1}{R_1}$$

Hence a tangent parallel to R_1 obtained from polygon p_3 to a circle of radius δ , with center at G , will be the line of action of R_1 . The other reaction R_r may be obtained similarly, or, alternatively, by proceeding from the fact that the line of action of R_r must pass through the intersection of the vertical of the load 1, and the line of action of R_1 , and be parallel to R_r in polygon p_3 . These two lines of action may be obtained in another manner, which for brevity will here be omitted.

42—*Intersection and Envelope Lines.* The geometrical locus of the intersections of R_1 and R_r is called the *line of intersection*: the curve tangent to the left reactions is the *left envelope line*, and the similar curve on the right is the *right envelope line*.

TEMPERATURE.

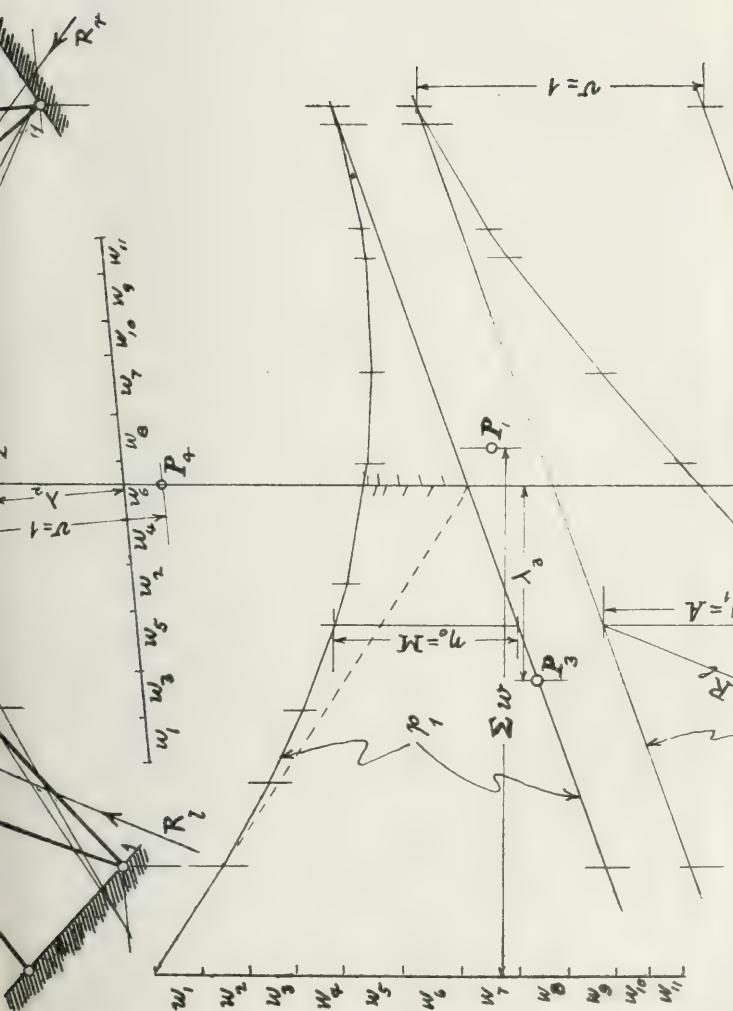
43—If the left end of the arch be free, and the right fixed, a variation t° in its temperature will change any unit lineal dimension to a length $1 \pm a t^\circ$, a being the coefficient of lineal temperature expansion, so that the span l of the arch will become $l (1 \pm a t^\circ)$; that is, the free end will be displaced by the amount $l. a. t^\circ$, but *without any rotation*. The reaction required at the free end to return it to its original position must, therefore, be such that no rotation is produced, which means that the line of action of such reaction due to temperature must pass through the elastic center G , and lie in the diameter conjugate to the normal to the chord of the arch (see par. 23).

Note.—The reader will note that the thrust, in our case, passes always through the point G (center of gravity of the elastic system). This is due to the fact that we assume that the imposts (skewbacks) of the arch dilate or contract exactly as the arch does. This is the case with reinforced concrete arches having very light piers, where the temperature has the same effect upon both piers and arch. In case the designer cannot, on account of the large dimensions of the piers, assume that the imposts move with the arch, then the thrust due to the temperature will no longer pass through G , but its position is determined, also graphically, by a method due to Müller-Breslau. The assumption of either hypothesis lies with the skill of the designer.

By the theory of the ellipse of elasticity, therefore, such displacement is given by:

$$l. a. t^\circ = H. \Sigma w. d. r$$

where H is the reaction, and $\Sigma w. d. r$ is the product of inertia of



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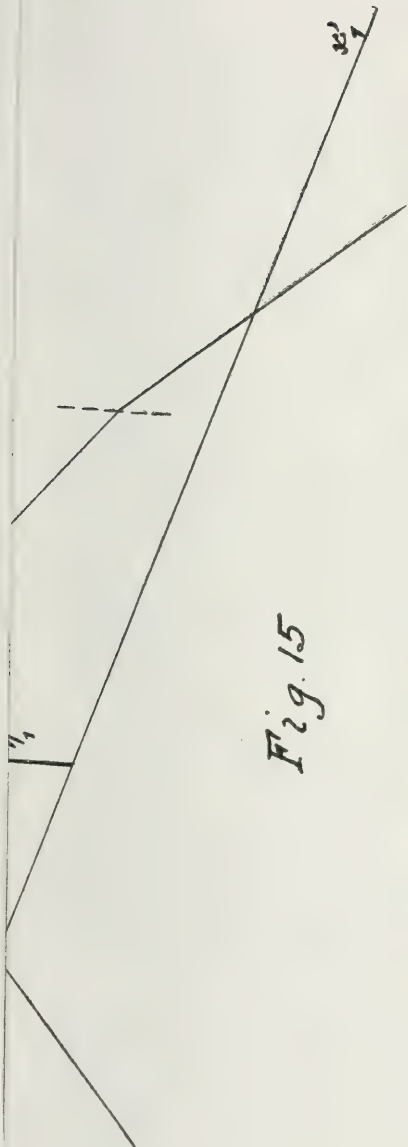
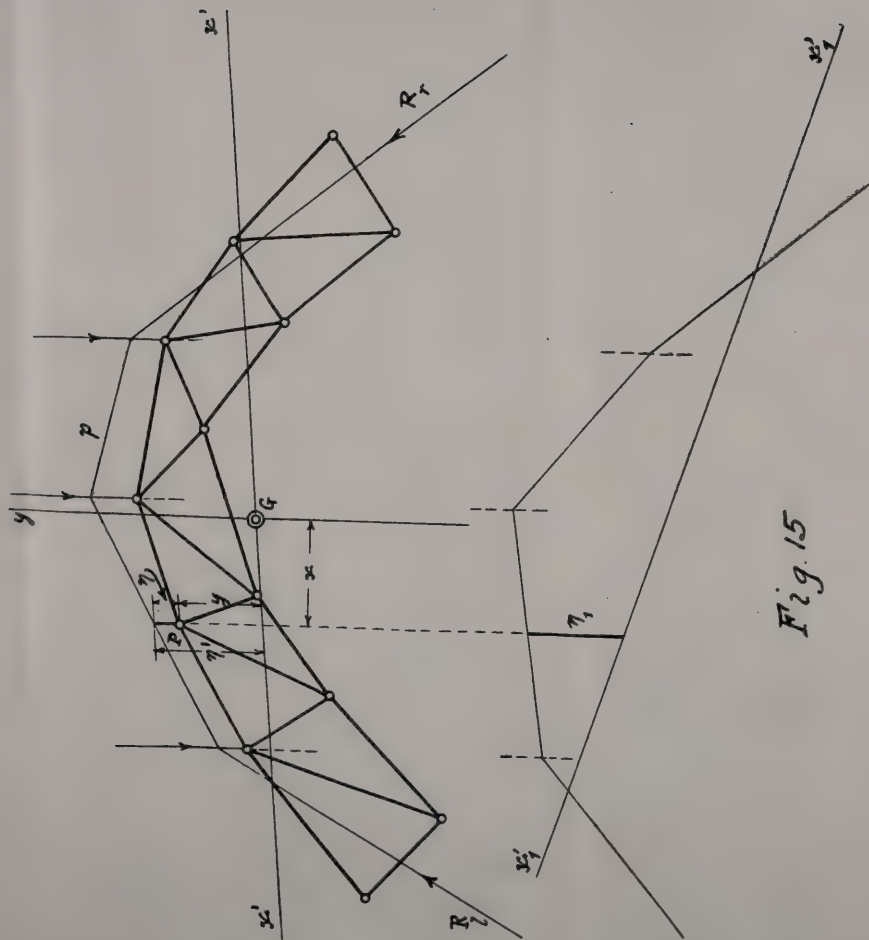


Fig. 15

376B.



the entire elastic system (Σw) with respect to the line of action of the force H and to the line of displacement.

Usually, however, the arch is symmetrical, and thus the force H acts along one of the axes of the ellipse of elasticity, and the product of inertia of Σw with respect to the axis x and the chord l degenerates into the moment of inertia of Σw with respect to x , i. e.,

$$l. a. t^0 = H. \Sigma w. \rho_x^2$$

where ρ_x is the semi-axis of the ellipse upon the axis y (par. 23). From the above equation:

$$H = \frac{a. t^0. l}{\Sigma w. \rho_x^2}$$

The quantities a , t^0 , and l , are known, and $\Sigma w. \rho_x^2$ is easily found (from either drawings Figs. 1 and 2), as is shown in the original paper.

If during the construction of the five polygons $p_1, p_2, \dots, p_n$, the value E entering the expression for Σw has, for simplicity, been assumed equal to unity, it is to be remembered that in computing now the value H the above fraction must be multiplied by the actual value of E as shown in the paper on the practical application.

(NOTE: The construction of all polygons by this graphical method is simplified to a remarkable extent where, as is usually the case, the arch is symmetrical with respect to its vertical axis.)

POLYGON OF PRESSURE FOR DEAD LOAD.

44—Let p (Fig. 15) be the polygon of pressure for dead load; η (measured parallel to the axis y) is the vertical distance between a pole P and this polygon; η' is the distance (parallel to y) between the same side of the polygon (at its intersection with η) and the axis x' . Then:

$$M = H. \eta = H (\eta' - y)$$

where y is the parallel distance between the axis x' and the pole P . By the theory of virtual work as applied to arch design, the equations of condition are:

$$\Sigma M. w = 0$$

$$\Sigma M. w. x = 0$$

$$\Sigma M. w. y = 0$$

which are the usual equations in which has been substituted w for

the value $\frac{s}{E. F. r^2}$ which is the elastic weight for a trussed rib

and is different from that for a solid rib (see par. 26).

Writing these equations as follows, with the value of M inserted, and H , which is the same for all terms, cancelled:

$$\begin{aligned}\Sigma w. \eta &= O \\ \Sigma w. \eta'. x &= O \\ \Sigma w. \eta. y &= O\end{aligned}$$

or, employing the value of η above given:

$$\begin{aligned}\Sigma w. \eta' - \Sigma w. y &= O \\ \Sigma w. \eta'. x - \Sigma w. x. y &= O \\ \Sigma w. \eta'. y - \Sigma w. y^2 &= O\end{aligned}$$

and taking the axis x' so that its direction is conjugate to that of y (par. 5) the sum of the products of inertia of w being therefore zero, and the static moments also, since the axis passes through G , the center of gravity, the three equations will finally assume the form:

$$\begin{aligned}\Sigma w. \eta' &= O \\ \Sigma w. \eta'. x &= O \\ \Sigma w. \eta'. y - \Sigma w. y^2 &= O\end{aligned}$$

since, as just stated, the sum of the static moments $w. y$ and of the products $w. x. y$ are zero. Interpreting these results, the first two of these equations make it evident that the axis x' passes through the center of gravity of the elastic system, even when the elastic weights of the system are supposed to be applied at meeting points of the verticals through the poles of the system and the polygon of pressure, instead of being applied at the poles themselves.

Assume an arbitrary polar distance H_1 (instead of one with the true but unknown reaction H as polar distance) for a force polygon (of dead loads), and construct the corresponding funicular polygon (tentative polygon). Find the axis x'_1 , which passes through the center of gravity of the elastic system on the supposition that the elastic weights are applied at the meeting points of the verticals through the poles with the sides of the tentative polygon, and furthermore conjugate to the vertical axis y ; this tentative polygon, together with its axis x'_1 , will be related to the true polygon (with the correct polar distance H , and the elastic weights applied as above) by a projective relation. They are homological by affinity (Cremona, p. 18), and the ratio of their affinity is definitely given by the third equation, which may be written in the form:

$$H. \Sigma (w. \eta'. y) - H. \Sigma (w. y^2) = O$$

and if η_1 is put for any ordinate of the polygon tentatively constructed, then the above equation becomes, in terms of η_1 and H_1

substituting in the first term for H its value $H_1 \frac{\eta_1}{\eta^1}$ given by the ratio

of affinity of the above homological polygons:

$$H_1 \cdot \Sigma (\omega \cdot \eta_1 \cdot y) - H \cdot \Sigma (\omega \cdot y^2) = 0$$

This gives:

$$\frac{H}{H_1} = \frac{\Sigma (\omega \cdot \eta_1 \cdot y)}{\Sigma (\omega \cdot y^2)}$$

The second member of this equation is figured readily in view of the fact that $\Sigma \omega \cdot \eta_1 \cdot y$ is the product of inertia of the whole system, which is given by $\lambda_1 \cdot \lambda_2 \cdot n_1$, and $\Sigma \omega \cdot y^2$ is the moment of inertia with respect to the diameter x' , which is given by $\lambda_1 \cdot \lambda_2 \cdot n$ (λ_1 and λ_2 being the same in both cases), substituting these values in the above equation:

$$\frac{H}{H_1} = \frac{n_1}{n}$$

which permits the construction of the true pressure polygon.

THE SOLID RIB ARCH.

45—The theory has first been developed for the truss rib, since this is simpler than the solid rib, and owing to the fact that, as far as deformation is concerned, a latticed rib may be substituted for a solid rib, as will become clear from the following demonstration:

Consider the solid rib to be divided into elementary lengths ds , with N and M a normal force and its moment with respect to the middle cross section of one of these elements. N is the resultant of all the external forces applied to the arch to the left, for example, of the section considered. The shear, as is customary, is neglected as being very small for arches.

46—The theory demonstrates that the deformation $\epsilon \cdot ds$ due to the elasticity of the material and temperature changes is given by the equation:

$$\epsilon \cdot ds = \frac{N \cdot ds}{E \cdot A} + a \cdot t^\circ \cdot ds$$

and the angle $d\theta$ of rotation of the terminal section of the element with respect to its first section is:

$$d\theta = \frac{M \cdot ds}{E \cdot I}$$

where: N = normal force,

E = modulus of elasticity,

A = area of cross section,

a = coefficient of expansion,

t = number of degrees of temperature change,

M = moment,

I = moment of inertia of cross section.

Imagine $u_1 u_2$ and $v_1 v_2$, Fig. 16, to be the geometrical axes of the upper and lower flanges of a certain hypothetical latticed arch, all material of the solid section being assumed concentrated in these flanges. $u_1 u_2$ and $v_1 v_2$ are, furthermore, assumed to be in the same plane with the force, and parallel to the geometrical axis

of the element considered. Let $\rho = \sqrt{\frac{I}{A}}$ be their distance from

the axis; also let v be the middle point of $v_1 v_2$, which will be assumed to be the pole of $u_1 u_2$, so that the lattice shall be constituted by $u_1 v, v u_2$; similarly for the point u .

The stresses, therefore, in the flanges $u_1 u_2, v_1 v_2$, due to the

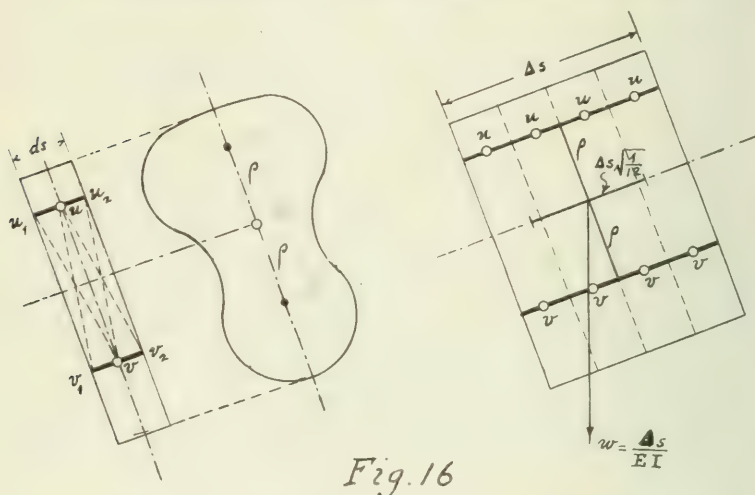


Fig. 16

force N and moment M with respect to the middle section of the element ds will be:

$$\frac{N\rho + M}{2\rho} = -\frac{N}{2} - \frac{M}{2\rho}$$

$$\frac{N\rho - M}{2\rho} = -\frac{N}{2} + \frac{M}{2\rho}$$

and the deformation of the panel $u_1 u_2 v_1 v_2$ of the hypothetical latticed arch, with regard only to the relative displacement of the terminal sections of the element ds , will be the same as for the solid element. In fact, due to the normal force N and the change of temperature t° , the points u_2 and v_2 will be displaced with respect to the points u_1 and v_1 in a direction parallel to the geometrical axis of the element ds , and such displacement will be equal to:

$$-\frac{\frac{N}{2} ds}{E \frac{A}{2}} + a. t^v. ds = -\frac{N. ds}{E. A} + a. t^v. ds = \epsilon. ds$$

and due to the moment M , the line $u_2 v_2$ will rotate with respect to the line $u_1 v_1$ about its middle point through an angle given by:

$$\frac{1}{\rho} \frac{\frac{M}{2\rho} ds}{E. \frac{A}{2}} = \frac{M. ds}{E. I} = d\theta$$

so that the evaluation of the statically indeterminate quantities and the deformations of the elastic arch with solid cross section is always possible by the substitution of the upper and lower flanges of a hypothetical latticed arch.

Moreover, it is legitimate to combine together sufficient infinitesimal elements ds to obtain a sum Δs , such that it may be regarded as a prismatic solid (Fig. 16), and then consider the centers of gravity of these elements Δs (centers of the points u and v for integral element Δs) as loaded by the elastic weights:

$$\int 2. \frac{ds}{E \frac{A}{2} (2\rho)^2} = \frac{\Delta s}{E. I} = w$$

provided that, after constructing the ellipse of elasticity (or, rather, the axes, as these only are needed) for each element (voussoir) Δs , corresponding to the points u and v of that element, the statical moments of the w 's, regarded as new forces, shall, in obtaining the moments of inertia and products of inertia of the w 's, be applied, not to the centers of gravity of the elements Δs , but to the antipoles of that axis with respect to the ellipse of elasticity of that voussoir. This follows from the fact that the antipoles are simply the centers of gravity of the elastic moments (compare paragraphs 4, 5, and 6).

The curvature of the arch could also be taken into consideration, but this is omitted for the present, as is also the question of the method of taking into consideration the effect of the yielding of the piers and the unequal settlement of the ground owing to the eccentric pressure due to the resultant. This may have considerable influence on the stresses in the arch, and may be taken account of by this method.

PERMISSIBLE DILUTION OF SEWAGE.

GEORGE W. FULLER, M. AM. SOC. C. E.

Presented at a meeting of the Hydraulic, Sanitary, and Municipal Section, October 21, 1912.

I was very glad to accept the invitation of the Western Society of Engineers to speak on "The Permissible Dilution of Sewage." Notwithstanding the fact that I was on the Missouri side in the drainage canal litigation some ten years ago, I am always glad to come to Chicago where there has been made so much history in this branch of sanitary engineering. This subject of the permissible limits of sewage dilution has many ramifications. When I accepted the invitation to come here and address you, I expected to be able to tell you something of my observations made during an inspection trip last summer in Europe. Unfortunately, I have been so occupied with other matters that I have not been able to prepare such a paper.

My purpose is not to devote my remarks to a review of the literature of this subject, but, on the contrary, to confine myself to the more salient features of the proposition and to point out those matters now receiving most discussion from sanitarians and now needing most careful consideration with respect to judgment and policy.

While I shall not dwell on the literature of this subject, I cannot refrain from pointing out that there has really been a great deal of information secured in this country with regard to the dilution method of sewage disposal. This is particularly true with regard to the Chicago drainage canal, the various streams of Massachusetts which have been reported upon by the Massachusetts State Board of Health, the general scheme of sewage disposal for the metropolitan district tributary to New York harbor, and more recently the various investigations which have been undertaken by numerous large cities, such as Philadelphia, Pittsburgh, Cleveland, Milwaukee. In my opinion it is very important for engineers and sanitarians having to deal with large sewage disposal projects to keep clearly in mind the experiences of others who have had to do with these matters under various conditions in different parts of the country.

At the outset it needs to be explained that the liquid portion of all sewage or water-carried waste must go to the water courses sooner or later. The only exception occurs where the sewage is evaporated. Mention is made of this feature in order to accentuate the thought that the water courses of this country must receive the water-borne wastes in some form or another. The question becomes, therefore, one of the degree to which liquid wastes are improved as to their quality before they are finally disposed of by dilution in some water course.

It is perfectly obvious that as civilization advances, and the population of the country increases, there can be no longer any streams of original pristine purity. That condition absolutely disappears, and such disappearance is one of the penalties of civilization. On the other hand, there are a great many streams in this country—some large ones, as well as numerous small ones—which are over-polluted with water-borne wastes. This is due to an overstepping of the proper limits of permissible dilution which we are to discuss this evening.

DEFINITIONS.

In order to make a little more plain, perhaps, my viewpoint, on some of these matters, I shall now speak of two or three definitions.

Sewage. I define *sewage* as the spent water supply of a community together with those trade wastes and street washings which in some instances are removed in underground channels called sewers.

Sewage Disposal. The *art of sewage disposal* means the economical elimination or prevention of nuisances with respect to these water-borne wastes.

Types of Nuisances. Nuisances due to sewage naturally are grouped into two classes: One refers to conditions that are offensive to the senses of sight and smell. The other refers to the hygienic aspect of the matter and to the transmission of disease germs contained in the sewage to neighboring communities through the water of the stream into which the sewage is discharged. These disease germs refer, of course, to those of the water-borne group, such as typhoid fever, Asiatic cholera, and others of intestinal origin.

The hygienic aspect of sewage disposal is naturally related in many instances to questions of water supply. It is also intimately associated with shellfish problems along the seaboard. Public health officials also have to deal with this aspect of the question with respect to public bath houses and possibilities of transmission of certain diseases by flies from deposits along the shore of some highly-polluted water courses.

HYGIENIC ASPECTS OF SEWAGE DISPOSAL.

The sterilization of sewage discharged into tidal waters in the general vicinity of shellfish layings has within the last few years proved an economical and, in the hands of careful operators, an efficient means of dealing with one of the important phases of the hygienic side of this question. While there are only a few sewage sterilization plants now in operation, there have been a dozen or more recommended for adoption and it seems unnecessary here to say more on this question in view of the thorough discussion which it has received from Professor Phelps in Water Supply and Irrigation Paper No. 229 of the U. S. Geological Survey. I am of the

opinion that hypochlorite of lime, or some similar sterilizing agent, has a great future before it in the treatment of sewage at places where shellfish are found within certain distances.

Sewage disposal in its relation to public water supplies is, of course, the most important hygienic feature, and it is a question upon which viewpoints vary widely. Some believe that all sewage should be purified so thoroughly that it will practically resemble spring water and so that there will be no need of water purification.

In my opinion all questions of water supply and sewage disposal should be viewed in the light of all local conditions, having in view that the treatment adopted should give the best returns for the money spent when due regard is given to the benefit derived in the interests of the public health.

The Royal Commission on Sewage Disposal of Great Britain has considered this question at length and its conclusion was as follows:

"We are satisfied that rivers generally, those traversing agricultural as well as those draining manufacturing or urban areas, are necessarily exposed to other pollutions besides sewage, and it appears to us, therefore, that any authority taking water from such rivers for the purpose of water supply must be held to be aware of the risks to which the water is exposed, and that it should be regarded as part of the duty of that authority, systematically and thoroughly, to purify the water before distributing it to their customers."

"Apart from the question of drinking waters, we find no evidence to show that the mere presence of organisms of a noxious character in a river constitutes a danger to public health or destroys the amenities of the river. Generally speaking, therefore, we do not consider that in the present state of knowledge, we should be justified in recommending that it should be the duty of a local authority to treat its sewage so that it should be bacteriologically pure."

In my opinion, the conclusion of the commission is a sound one and as a general proposition water purification rather than sewage purification affords a better safeguard of the public health in the present state of the art. It is also to be noted that water purification is not only more reliable, but it is also cheaper under most conditions.

In this connection it is to be borne in mind that untreated surface water supplies as a rule do not afford a thoroughly safe drinking water. The reason of this is that there are too many opportunities for pollution from the soil wash and indirect sewerage of small villages and hamlets, and the infection of the water from the casual huntsman, fisherman, or those who for pleasure or busi-

ness traverse the watershed. There are, of course, exceptions to this rule, but they are growing fewer and fewer. This is well shown in Europe where, since the great cholera epidemic of Hamburg some years ago, it is an unwritten but practically effective law that all surface water supplies shall be filtered.

Many large cities in this country are provided with combined sewers, the entire flow of which at times of storms can scarcely be purified completely. It is true that hypochlorite of lime has proved to be of much help in securing an improved quality of drinking water at many places, but the fact remains that as a general proposition the surface water supplies in this country should be filtered in order to make them thoroughly first-class in point of hygienic character.

While it is believed that the purification of public water supplies in this country is a subject that must stand on its own feet first and foremost, it is undoubtedly true that there are some exceptions to this rule and that sewage purification sometimes should be provided to aid the neighboring water supply. The medical man feels that everything that can be done to destroy disease germs should be done, and is inclined to say purify all sewage and also purify all water. This brings up the question of much practical significance of how a certain expenditure of money can be best applied in the interests of the public health.

In my opinion, the water purification should come first so far as the hygienic side of the matter is concerned, and sewage purification or perhaps sewage treatment by sterilization should come into play in order to make sure that water filters are not overloaded if there is likelihood of inferior quality of filtered water being furnished the consumers.

Double filtration of water supplies and the judicious use of sterilizing arrangements and the advantageous employment of coagulating processes can all be brought to the aid of the water purification plant. Even with all of these precautions as to the water supply, there are times when purification of the sewage of a neighboring community or of the community whose water supply is under consideration, should be carefully provided for. We shall say no more on this question of the hygienic aspects of sewage disposal, as it is hoped that the viewpoint has been made plain that the dilution method of sewage disposal is not barred from this line under ordinary circumstances. The limitations in the dilution method are really to be found in relation to the nuisance question as noted by sense and smell, and this is the question that we shall now proceed to discuss at length.

NUISANCES AS RELATED TO SEWAGE DILUTION.

Sewage dilution is an important, rational, and proper method of disposal of sewage if it is properly applied and is not abused. Disregarding the question of disease germs which we have already considered, the dilution method of disposal is a proper one when by

dispersion in water the impurities of the sewage are consumed by bacteria and larger forms of plant and animal life, or otherwise disposed of so that no nuisance results.

The dilution method is by far the most prevalent one now in use in this country. As our knowledge becomes more precise as to its advantages and disadvantages, the conclusion becomes more clear that the method has not been applied in a satisfactory way in a large number of instances. On the other hand, there seems to be no good reason why advantage should not be taken of this method within reasonable limits. Between the so-called complete purification of the sewage and the dilution method there are intermediate procedures which allow advantage in point of economy to be taken of the dilution methods, and at the same time the nuisances to sight and smell, which have been so common at various places, may be effectively prevented.

Nuisances attending the sewage dilution method may be due to the following:

1. Floating solids.
2. Settling solids.
3. Non-settling putrescible organic matters.

These three constituents, or groups of constituents, in sewage explain most of the difficulties that are encountered today with the sewage dilution method. We can all recall instances where orange peel and other household wastes float in bodies of water around sewer outlets. We are also accustomed to deposits of "sewage mud" or sludge near the outlets, and the likelihood of their decomposing and producing foul odors particularly at times of low stream flow. There is also the condition where there is inadequate dilution of the sewage as it enters the stream, and where the entire body of water turns black owing to anaerobic decomposition or so-called septic action.

Clean Rivers. There is undoubtedly a well-defined movement on foot to free American rivers of small and moderate size of solid organic matter and filth coming from the flow of sewers. This movement, in my opinion, is a proper one and, when combined with adequate purification of water drawn from rivers receiving such sewage, the whole question of sewage disposal by dilution assumes a more reasonable and favorable aspect than hitherto. Furthermore, it does not involve communities in the expense called for by sewage filtration. It modifies, however, the limits that are permissible as to sewage dilution and calls for a recasting of the engineer's views and calculations upon the question. We shall outline briefly some of the features involved in the permissible limits of sewage dilution in connection with "clean rivers."

Screens. In America there has not been as much progress as in Europe in the use of screens or other arrangements by which floating matters objectionable to the sight are removed from sewage as it enters the stream. In Germany so-called fine screens with an

opening of 0.4 in. or less have had many warm advocates. The fine screens have not the standing today that they had a few years ago, in the opinion of many engineers, owing to the success attending the sedimentation devices as a cheaper and simpler means of keeping back floating matters and at the same time of removing the coarse heavy solids that subside. In America fine screens have been regarded with questionable favor, owing to the cost of their maintenance. We shall not discuss the relative merits of different devices, but will confine ourselves to the statement that without question floating matters should be removed from sewage before the latter is disposed of by dilution in an adequate body of water.

Sedimentation Tanks. An examination of the Massachusetts State Board of Health reports, and other American data on pollution of streams, quickly shows that the stranding of solids in the vicinity of sewer outlets has in the past proved one of the drawbacks to the satisfactory use of the dilution method. This is particularly true at times of low river stages when banks of "sewage mud" or sewage sludge are exposed to "putrefaction" with attendant bad odors. Some 60% of the total suspended solids in the ordinary sewage are responsive to subsidence, and unless the sewage is discharged into a river with uniformly high velocities, these solids are bound to strand or settle. The removal of these "settling solids" is an important feature in the establishment of "clean rivers" in this country and, if we eliminate a few of the larger streams, it is my opinion that sedimentation of sewage is going to come into general use as a preliminary step in the modern arrangements for sewage dilution.

In earlier days difficulties in disposing of the sewage sludge or solid matters deposited in tanks were the cause of the slow adoption of this important improvement. It is true that chemical precipitation and sludge presses provided a solution of the problem, but at an expense that proved discouraging to many communities, and such that in Europe the cities near the seacoast were led to "barging" the sludge to sea. It is believed that septicization, particularly as embodied in tanks of the two-story type, will allow this matter in the future to be handled far more satisfactorily than in the past.

Unimportance of Organic Matter in Settled Sewage. If a sewage has been clarified to such an extent that there will be no deposits in the stream bed at or near the sewer outlet, and if the disease germs are killed, there then remains to be considered the sanitary significance of organic matter coming from the settled sewage, and diluted with large volumes of river water. In most cases where the sewage is diluted so that there is formed no offensive odors due to decomposition, and where the sewage has undergone sterilization, it does not seem likely to us that it is necessary in the interests of the public health to go to the expense in most cases of removing the dead organic matter of the settled sewage.

It is intimated by some that the germ theory of disease and the specific infection of water through disease germs does not neces-

sarily tell the whole story as to the hygienic disadvantages of sewage-polluted waterways. On the other hand, the extensive investigations of the United States National Board of Health, as stated in their report for 1882, page 201, indicate that with sewage-polluted waters, it would be necessary to drink half a gallon at once of the waters under test in order to get as much nitrogen and carbon as is contained in a single medicinal dose of strychnine, which is stated to be one of the most energetic of recognized poisons.

A similar view as to the harmlessness of organic matter *per se* was stated by the late Dr. T. M. Drown in the Special Report of the Massachusetts State Board of Health, 1890, Part I, page 537.

More recently a similar view has been given by Dr. A. C. Houston, now Chief Water Examiner of the Metropolitan Water Board of London, in the Second Report of the Royal Commission on Sewage Disposal, page 27:

“Organic matter *per se* in water is seemingly harmless; it is the bacteria likely to be associated with the organic matter that constitute the element of danger. Only bacterioscopic analysis can hope to reveal the kinds of bacteria in an effluent which are of a sort liable to be related to disease. Chemistry is quite powerless in this respect, and, indeed, all chemical standards of potability are apparently based on an assumed relationship, which may or may not exist, between the amount of organic matter and the number and kinds of the associated bacteria. Typhoid fever stools, whether sterilized and innocuous, or unsterilized and highly dangerous, would yield to chemical testing practically the same results as regards the nature and amount of organic matter present.”

Furthermore, where there is adequate dilution of settled and sterilized sewage in a river used for a water supply, it is not difficult, as already stated, to effect a substantial removal of organic matters in works well adapted for water purification and involving coagulation, aeration, and sterilization by powerful oxidizing agents.

Degree of Dilution. On the assumption that floating and settling solid matters are removed from the sewage and that disease germs are killed, where necessary, by sterilizing chemicals, we can now come to the discussion of what the permissible limits are for the dilution of sewage. We can answer it by saying first that the limits should be such that there should be present at all times and in all places sufficient dissolved oxygen to prevent anaerobic or so-called putrefactive decomposition becoming established, and furthermore that there should be a reasonable margin of dissolved oxygen to take care of fish life unless it should prove in some instances that the question of fish life is not of sufficient significance to justify consideration.

On the degree of dilution the first scientific data in this country were obtained in the early days of the consideration of the Chicago

drainage canal, and it is from the technical staff of the Chicago Sanitary District that engineers have received their latest information bearing upon this important subject. A few years ago, and in fact until quite recently, all data as to the degree of dilution of sewage referred to crude sewage with its floating and settling solids. The Chicago drainage canal was established on the legal limit of 3 1/3 cu. ft. of water per second to dilute the sewage of each 1,000 persons connected with the sewers. That limit was probably too low for the crude sewage of a city which has such a large proportion of manufacturing wastes in its sewage flow as is the case here in Chicago. For a city without manufacturing wastes it is probably a fair limit, although some data obtained from Massachusetts suggest that it might be wiser to provide a somewhat more liberal volume of water for dilution.

To my mind a dilution of 4 cu. ft. per second per 1,000 population is as close a general figure for crude sewage as can now be obtained, although undoubtedly there are various local factors which influence the dilution and may establish a range as wide as from 3 to 7 cu. ft.

As to the degree of dilution necessary for settled sewage, present evidence indicates that at least 2.5 cu. ft. per second per 1,000 population should be provided for residential communities and where the diluting water is well supplied with atmospheric oxygen. For manufacturing cities, where the diluting water is moderately depleted in oxygen during the summer months, this dilution may perhaps have to be doubled, that is, increased to 5 cu. ft. per second per 1,000 population.

There is no precise rule now available, and the above ranges establish as closely as can now be done the permissible limits in the dilution which properly should be applied to settled sewage in preference to raw sewage with floating and settling solids in it.

Dispersion,—Mixing. One of the great drawbacks to the dilution method of sewage disposal as applied in earlier years was then the tendency to conduct the sewage only to the margin of the stream and perhaps only to the high-water shore line. This explains the nuisances that prevail in many American cities where the stream flow throughout the entire cross-section of the river is sufficient to provide reasonable results by the dilution method. Enough has been said to indicate that if dilution is to be advantageously used, it should be done under conditions where the sewage is so mixed with the stream flow that the degree of dilution above mentioned will be secured at all points. Naturally, streams with comparatively high velocities allow better results to be obtained than those in which the velocity is reduced or checked entirely at times by mill ponds or other obstructions.

Residual Oxygen. This is a question upon which there are many divergent views. Until it is put on a more satisfactory basis than at present, it is hardly feasible to state the degree of permis-

sible dilution more closely than given above. Colonel Black and Professor Phelps have advocated that a residual margin of 70% of dissolved oxygen should be provided for the waters of New York bay. A more common opinion places this margin at 50%. Messrs. Wisner and Pearse (of the Sanitary District of Chicago) have put this margin at 2.5 c.c. of dissolved oxygen per liter, which is equal to about 20% of saturation of oxygen during winter months, and 30% for the summer temperatures. These gentlemen, however, have reference to fish life. My own experience is that if stranded solids have been kept out of the stream there will be no occasion for difficulty as to anaerobic or putrefactive decomposition, provided there is some dissolved oxygen present in the stream at all times and at all places. One of the earliest and most important points established at the Lawrence Experiment Station was that a little oxygen, say 1% to 3% of that necessary for saturation, would allow oxidation and nitrification to take place as satisfactorily or nearly so, as if the water were saturated with oxygen. I know of no reason for departing from the teachings of those early experiments at Lawrence, and I believe that estimates of 50 or 70% for the required residual of dissolved oxygen can be explained only by extraordinary allowances made for the consumption of oxygen by existing sewage sludge, or by more than liberal allowances of oxygen for major fish life. In fact, whatever margin is needed above a slight positive quantity at all times and places in the stream is, in my opinion, solely accountable for by the oxygen necessary for fish.

Fish Requirements. Data are somewhat meagre as to the amount of dissolved atmospheric oxygen which is required in the streams to protect major fish life. The quantity no doubt varies with different species of fish and perhaps other local conditions. In the Lower Elbe near Hamburg it is stated that the margin of dissolved oxygen during the ordinary summer periods falls as low as 20%, and the figure in the Lower Thames is understood to be about 30%. At Hamburg there has been no serious complication as to fish life other than during the summer of 1911, when it is understood that for three or four weeks fish actually migrated from the vicinity of the city. This does not mean that there was any nuisance as to putrefactive odors. In fact, it is stated that none existed. It shows also another point and that is that since the fish returned after a period of three or four weeks, it will be quite debatable whether once or twice in a generation it is necessary to prevent the migration of fish, if by such prevention there will be involved expenditures of vast sums of money for the more complete purification of the sewage.

I was told in Berlin last summer that an amount of residual dissolved oxygen equal to 1 c.c. per liter was considered sufficient under ordinary circumstances in the immediate vicinity of a sewer outlet, although 1.5 c.c. were preferable.

Fungus Growth. Professor Thumm, of Berlin, has stated to me that in waters containing a great abundance of oxygen it is possible that offensive odors might result through the growth of certain fungi, namely, *Leptomitius*, *Sphaerotilus* and *Cladothrix*. The staff of the Royal Prussian Testing Station have observed that these growths are said to be characteristic of streams receiving a lot of industrial wastes, such as come from wood pulp mills. The growths seem to be favored by the presence of much putrescible organic matter, ample dissolved oxygen, and a high velocity of stream flow. These comments are not in harmony with my recollections of the life history of these organisms, unless it be that their growth is fostered in certain deposits which are dislodged under certain conditions. The question is an interesting one, and it is the only suggestion that I have heard of which limits the permissible dilution of sewage in other than by the dissolved oxygen, in cases where disease germs are destroyed or may be properly ignored. This is a question which needs further study, and it may be entitled to more consideration than we now realize in America.

Comprehensive Designs. While I am a firm believer in the dilution method of sewage disposal within permissible limits which I have tried roughly to outline above, I am aware that many American towns and cities are likely to grow to proportions where the dilution method will require more and more complete treatment of the sewage in order to be satisfactory. I believe that it is the part of wisdom to prepare designs for sewage disposal works so that if filtration is not needed at the outset it can be adopted as conveniently as practicable in later years and without embodying too great a sacrifice in works now undertaken. This means, among other things, that intercepting sewers, sites for screening plants, and sedimentation tanks could well be arranged with the idea that some day filtration also must be provided. If this were done it would probably save considerable money that otherwise might be lost.

Relaxations. In England I found the principal topic of conversation among engineers to be the forthcoming report of the Royal Commission on Sewage Disposal and the disposition in that report to provide for "relaxations." By this is meant that there would be installed, piecemeal, works which would provide ultimately for purification to the degree set out by standards recommended by the commission a few years ago. It is proposed now to take full reasonable advantage of dilution, but to arrange the works, as I understand it, so that further and more complete treatment may be secured when and as required in the future. I believe this is a reasonable program, and it is what I have had in mind in connection with a number of recent problems in this country and also when I made my remarks above with respect to "comprehensive designs."

Separate Sewers. So far as household wastes are concerned, I believe that in all new systems and in many cases of extensions to

existing sewer systems, it will be helpful to adopt the "separate system" to a greater extent than has been the vogue hitherto. The prevention of a mixture of the sanitary wastes of the household with the storm water from the streets will aid materially in minimizing the expense and in increasing the success attending sewage purification, sewage treatment, and the utilization of the dilution method within safe practicable lines.

SUMMARY.

It is permissible to dispose of sewage by dilution provided that complications can be prevented so far as disease germs are concerned, and this should be best done in connection with water filtration, and further provided that offensive conditions to sight and smell do not result.

In some large streams, as in the lower Mississippi near New Orleans, sewage which is passed through coarse screens may with care be disposed of in a satisfactory way. In large lakes, tidal estuaries, moderate and small streams, it is important, if not necessary, for the success of maintaining "clean rivers" or "clean bodies of water" to free the sewage from floating and settling solids.

Permissible dilution of sewage without treatment in water courses with fairly high velocities ranges apparently from about 3.5 to 7 cu. ft. per second per 1,000 population, depending upon the manufacturing wastes in the sewage and the dissolved oxygen content of the diluting water. For well settled sewage, these limits become about 2.5 to 5 cu. ft. per second per 1,000 population according to present information.

DISCUSSION.

Prof. Edwin O. Jordan (University of Chicago): The author has given us a very clear, comprehensive, and authoritative statement which, of course, has a most important bearing upon the situation here in Chicago.

I want to express my entire agreement with the author in his sharp distinction between the hygienic aspects of dilution and the question of preventing a nuisance. It seems to me these matters should be recognized as quite distinct. I find, among medical men especially (some of my very good friends, in fact), a feeling that no crude sewage ought to be turned into any water course under any conditions. There is a good deal of talk, as you know, about "turning our waterways into open sewers," and a great deal of the criticism of engineers who advocate the disposal of sewage by dilution is made on the ground of this feeling, a feeling which seems to me is clearly due to a fundamental misunderstanding as to just what dilution aims at. As the author has told us, dilution does not attempt to purify sewage. There is a distinction between the purification of sewage and the treatment or disposal of sewage that must always, I think, be kept in mind in such discussions. It may be pointed out, by the way, that to a certain extent dilution does

diminish the danger of infection. If a sewage is diluted, let us say, 1 to 20, there is a reduction in the given volume of perhaps 95% of the disease germs,—a percentage of reduction which compares not unfavorably with the reduction that is observed sometimes in certain types of filters treating a highly polluted water; but that, of course, is not what dilution sets out to accomplish.

Dilution, as we have heard tonight, is primarily for the purpose of preventing a nuisance. The question of protecting the health of the community against typhoid fever must be dealt with in an entirely different way than by the extreme purification of sewage. In the Lawrence experiments alluded to, there was one sand tank through which sewage could be run slowly through 5 ft. of sand. The sewage, in passing through this tank, was purified to such an extent that the effluent was practically as good as pure spring water, and was almost bacterially sterile. There was no odor; it was clear and sparkling, tasted just like spring water, and compared, on the basis of chemical composition, very favorably with many spring waters sold on the streets of Boston at that time.

But as a rule that is not the sort of thing a community can afford to pay for in the treatment of sewage. I speak of that as a remarkable and extreme instance of possibilities in sewage purification. The task with which most communities are primarily concerned is disposing of the sewage in such a way as not to occasion a nuisance. The protection of the health of the community against typhoid fever and other water-borne diseases can best be achieved by purification of the water supply, by putting the barrier at that point rather than at the point of sewage disposal.

The author, in speaking of the dangers of infection from surface waters, very properly spoke of the extent to which increasing civilization and increasing density of population have brought about an increased danger from this source. In that connection I wish to add that we have, to a large extent, learned the lesson of avoiding that danger in the more civilized and densely settled parts of the country. We have learned to leave surface waters alone as a source of water supply. As evidence of that I simply need to point to the distribution of typhoid fever, water-borne typhoid, in this country at present. As a water-borne disease, typhoid fever is more common in the thinly settled states on the edge of civilization. There is at the present time a considerable outbreak of typhoid fever in one of the towns in Montana on the edge of Yellowstone Park, thought to be due to slight accidental contamination of the water source by campers who happened to be typhoid carriers. So far as the protection of surface waters is concerned, it is the thinly settled parts of the country that need that protection quite as much as the more civilized portions.

One other point strongly impressed me while the author was speaking, namely, the way in which knowledge in all these matters is becoming constantly more precise. Not so very long ago we were all very much afraid of sewage, just as a good many people

were, and still are afraid of garbage as a source of disease. We are now passing over that stage. A good deal of fear has been expressed at improper methods of sewage disposal. If we guard our water supplies, the question of sewage disposal can be looked at largely as a question of the prevention of a nuisance.

W. S. Shields, M. W. S. E.: This paper is both valuable and timely,—valuable because of the facts stated by such an authority and which are not found in print; timely because sanitary engineers are hesitating to recommend the expenditure of large sums of money for sewage-treatment plants until better results have been secured from some plants now in operation.

My own observations and a study of sewage-treatment plants have forced upon me the conclusion that there are thousands of dollars expended for such purposes from which little value is received in return because of the lack of care given the plants by the officials in charge. In many cases better results might be obtained by a less expensive plant than are now obtained because of the lack of care.

Take the cities located upon the Great Lakes. It is not improbable that some system of partial treatment of sewage will be found which may make safe the discharge of an effluent therefrom into the lakes at a given distance from a water supply intake.

Much has been accomplished by the study of methods of sewage treatment, but little information is available of the effect of tank treatment preceding dilution and the rates of dilution necessary for such effluents.

At Fond du Lac, Wis., the sewage from a system of sanitary sewers is pumped into the Fond du Lac river at a point approximately a half mile from its outlet into Lake Winnebago. Some years ago the city installed a system of treatment consisting of septic tanks and contact beds, which after a short time were abandoned. The city has recently adopted plans for the rebuilding of these tanks upon the Imhoff principle, and providing a plant for treating the effluent with hypochlorite of lime before discharging it into the river. There is no water supply taken from the lake nearer than 20 miles from the mouth of the river, and in this case the supply is filtered. The elevation of the flow line of the tank is sufficient to allow filters to be constructed and operated should they be found necessary.

In the preparation of the plans for the Fond du Lac work, little information could be found relative to the probable effect of discharging a treated tank effluent into a stream where final purification must be secured by dilution. It is hoped that the operation of this plant may indicate what can be expected of this method of treatment.

C. D. Hill, M. W. S. E.: Where solids are stranded in the bottom of the stream, and where one depends upon the dilution method, will the gases of decomposition have a reducing effect upon the con-

tained oxygen in the water, and thereby interfere with the oxidation of the suspended matter in the water?

Mr. Fuller: I presume that would be the effect, to a small degree, so far as the gases are concerned. I think most of those gases are quite stable. Marsh gas is certainly a stable gas and I do not believe it uses up oxygen unless it is removed at the point of origin. With oxygen, each of the very complex organic molecules in its original condition may have as an exponent x . We will have c^x and n^x and all of those different atoms in a complex compound. If you subtract the simple gases of decomposition like marsh gas, CH_4 , sulphureted hydrogen, and products of that sort and hydrogen itself, of course there must be left intermediate products. Some of those are probably quite unstable and they probably do use up oxygen to a considerable extent; so that it is true, in my opinion, that there is more or less of the oxygen of the overlying liquid that is eliminated from use in oxidizing the soluble and non-settling portions of sewage above, due to withdrawal in some way of the oxygen by the products of sludge decomposition below.

Mr. Hill: If 4 cu. ft. per second is sufficient dilution for the crude sewage of a certain community, then if we eliminate the settling solids, what would be your estimate of the amount of dilution that would be necessary? Could the 4 cu. ft. be reduced?

Mr. Fuller: Yes, that could probably be reduced, somewhat.

Mr. Hill: Would you venture an estimate?

Mr. Fuller: No, I do not think we know enough about that to say precisely. I think that the solid matters as we find them in the laboratory are more stable than the liquid portion and non-settling portion as to their ability to use up oxygen. But there must be a relationship there about which we do not know a great deal.

Mr. Hill: That, of course, is a practical proposition here, because we have reached the limit of our dilution method; we are proposing to put in settling basins and, with the amount of dilution we have now, take care of the increase.

Mr. Fuller: I have no doubt that is feasible within certain limits.

Mr. Hill: If the effluent from a settling tank is treated with hypochlorite of lime, would that have the effect of sterilizing the aerobic bacteria and prevent further decomposition, or could you depend upon other aerobic bacteria found in the stream? Do you think the sterilization would be prejudicial to further purification?

Mr. Fuller: I think it would not make any great difference, and it would doubtless be desirable in some ways. You simply would not use up oxygen so fast. As I understand it, the dilution method does not depend upon, nor is it intimately related to, an actual and direct oxidizing of organic matter. The amount of oxidizable crude organic matter in soluble and non-settling form

is not of special importance one way or another. It is of importance to maintain this oxygen balance, and to have enough oxygen present at all times so that when the bacteria do attack this organic matter they are not put off on to an anaerobic or putrefactive basis.

It is possible, from a standpoint of bottle experiments with hypochlorite, to get effluents without great expenditure of money which will stay in a stable condition, rather suggesting that if one had an effluent pipe where he could lead that effluent without getting it infected or mixed up with bacteria from soil washings or from the stream-bed, he could get along very well. But I imagine if such an effluent were discharged into a stream, the bacteria naturally present in the flowing water, if there was any stirring up or changing of velocities of stream flows, particularly around mill ponds, would not be a specially healthful thing. Mr. Shields also spoke of that feature.

In the East, state departments of health recognize favorably sedimentation where tanks hold two to four hours' flow, and provisions to sterilize that effluent with a liberal amount of hypochlorite of lime. I think that is a method which is taken quite kindly to by the departments of health, subject to two limitations. That is, they are always afraid that there will be no hypochlorite applied at night. (They have always been inclined to look with favor upon some automatic arrangement, which it is possible to design.) The other feature that the state boards of health do not take a special fancy to, is over-treatment with hypochlorite of lime, resulting in the killing of fish.

Langdon Pearse, M. W. S. E.: I might perhaps answer Mr. Hill's questions in a rough way and say that some experiments have been made in the laboratory of the Sanitary District of Chicago, at 39th street, and we find that the improvement due to settling, for instance, is not at all in the ratio of the removal of the suspended matter. If we have 45 to 60% removal of suspended matter, we find that the improvement perhaps from the standpoint of the oxygen consumption is from 25 to 30%. It is rather difficult to make experiments in an accurate way, but our chemist, Dr. Lederer, has found, in that rough way, that such an improvement, in connection with the sewage with which we are dealing there, can be expected. It is worth while, perhaps, to call the attention of the engineers to the sense of proportion when dealing with such a material as sewage; that is, it is a varying liquid; and when we consider the small sample that is taken from the large volume that is passing, it is a source of wonder to me sometimes that results come out as accurately as they do. For instance, when we are studying the drainage canal at Lockport, we may take out a gallon in a day from a stream which is flowing many hundred million gallons in the course of a day, and yet year in and year out our results have a consistent bearing, which speaks well for what is going on in the streams.

We have found the matter of mixing, that the author men-

tions, quite important. There is considerable difference in the drainage canal for the first few miles, until it is sufficiently turned over and worked from shore to shore. This happens in the first four or five miles, so that by the time Summit is reached, the liquid is well mixed. There is quite a difference noted at Kedzie avenue and as far as Cicero between the two banks. That is partly because of the construction of the piers of the drawbridges, which obstruct one side of the channel and make a current on the south side, so that side usually is in better condition, as I recall it, than the other, where tested. However, better conditions would result if we could introduce the sewage from underneath the stream and avoid the objectionable sewer outlets, especially the kind where the bridge builders and the abutting property owners have left piling, which makes places that never cleanse.

There is a tendency on the part of the community to blame odors and occurrences that are not wholly understandable, to sewage disposal. A report came to us that there was considerable nuisance at a certain sewage outlet, which might be due to the drainage canal; the man didn't quite know; it was a convenient thing to blame. We investigated the matter, and the conclusion reached was that a pit of the rolling lift bridge had been allowed to collect the street washings, thereby forming a septic tank and causing trouble. That is something the engineer may not think of when designing such structures.

The sewers themselves are frequently productive of odor, if deposits form. With the flat grades in vogue in Chicago, on most corners one can usually get a strong odor from the catch-basin inlet. I do not speak of this as a criticism of the sewer department, in any sense, but simply as a fact that is worthy of observing and avoiding where it is possible to get scouring grade.

The Bubbly Creek situation is quite a pressing one. In some ways it is rather remarkable (situated as it is in a hot-bed of odors) that so much attention has been drawn to it. One can smell the Stock Yards three or four miles away, or more, when winds are favorable. I do not believe one can distinguish Bubbly Creek in the general odor. However, the situation, while improved of recent years, is not yet cleared up. Negotiations are in progress to try to solve the problem of keeping Bubbly Creek clean. It may interest some of our members to know that we have a small experiment station at the Stock Yards, at 39th street, and at Center avenue. In dry weather the suspended matter runs from 200 to 800 parts per million gallons on daily averages. The sewage is also warm, which will probably give added troubles in promoting rapid septic action, which we are desirous of avoiding in our settling tank.

THE REGULATION OF PUBLIC UTILITIES IN WISCONSIN

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Presented March 24, 1913.

While governmental regulation of public utilities in the United States as now known is a recent development, the principles fundamental thereto were really laid down during the development of the European common law in mediæval times. In fact, the broad, humane doctrine that no man shall use his own to the detriment of his fellow has probably from time to time been applied to the business activities of most civilized peoples. In the first and second centuries the Roman government regulated practically everything. About the year 300 A. D. an imperial edict was issued fixing a maximum price for meat, salt, fruits, corn, wine, clothing, timber and the wages of artisans. From the sources at hand, however, it seems that effective regulation of rates and services as a general governmental policy found its beginning during the middle ages.

In England, for example, from about the thirteenth to the sixteenth century public control was exercised over most private enterprises engaged in supplying public necessities. Thus the baker was compelled to serve all equitably at stipulated prices. The innkeeper sold ale at prices in measures prescribed by the government. No corner for the purpose of enhancing prices was allowed on food products. Compulsory service applied to physicians and surgeons. A definite schedule of wagon freights existed and was enforced by each county judge. An act to regulate boatmen on the Thames provided for uniform rates which were required to be posted in public places. Eight of the boatmen were elected overseers, while the mayor and court of aldermen acted as a commission to hear complaints. Such occupations as miller, barber, tailor, and grocer were subject to control. Rents for the use of wharfs and prices for coal were required to be reasonable. In the United States during colonial days regulation was in vogue. The prices for rum, tobacco and bread in New England were fixed. Smiths were compelled to repair wagons under fair charges. Excessive retail prices were placed under the ban of colonial law.

All this was effected under the common law, a body of rules which have often been termed the consensus of judgments of common sense men, or the common sense rules of human conduct. It rests upon the principles that no one shall so use his own as to bring injury upon the many, and that he who devotes his private property to a public use thereby clothes it with public interest. The

common law duties of public utilities today are to adequately serve all who apply at reasonable prices without unjust discrimination.

The earlier systems of regulation were in the latter part of the eighteenth century superseded by the well known *laissez faire* policy under which competition was mainly relied upon for the establishment of fair prices and adequate service. This policy was argued by the radicals of that day who sought industrial freedom by demanding that the government keep hands off and leave each individual free through competition to work out his own industrial salvation. While the policy is well adapted to the subduing of the forest and the prairie, it does not seem to be well fitted for the regulation of public utilities. It has in fact been found to be entirely inadequate for the proper regulation of the prices and other conditions of such services. A free hand in exploiting the material world leads to wholly different results from those which are had from unrestricted exploitation of the social world. The results in the latter case are bad from an economic as well as from a social point of view. And this fact has in turn led to a well-developed sentiment in favor of abandoning the competitive policy in the public utility field and to substituting therefor government regulation. In fact, in America and England the competitive or let alone policy has never been fully adopted for such facilities as water or canal transportation, toll bridges and turnpikes.

This demand and need for the return to government regulation of industries and services that are fraught with public interest has grown very rapidly during the past fifty years or more and this development has been brought about by the great changes that have taken place in economic and social conditions. The construction of steam railroad and telegraph systems completely revolutionized business methods and modes of living. Parallel with the consolidation and growth of business units, due to better transportation, came the concentration of population into urban centers. To meet the needs for the comfort of urban dwellers, private enterprises in time, as the inventions were commercially perfected, established city water and gas supply systems, electric light and power plants, horse and power street railway lines, telephone exchanges and heating utilities. In most cases where effective competition existed it was soon eliminated by consolidation. Through education and campaigns for the promotion of business the utility service, looked upon at first as a luxury by many, soon became a household necessity. The need for this service in daily life, the serious abuses which have developed in connection with the furnishing of such service and their far-reaching effect upon society as a whole; and the further fact that existing remedies did not appear to be adequate for properly adjusting these abuses have caused many states to create special laws for this purpose and to provide special commissions for administering these laws.

Wisconsin has such laws as well as such commissions. Of

these laws those which relate to railroads and other carriers were enacted in 1905; while those which relate to other public utilities were enacted in 1907. The great number of complaints and other work which this Commission has to pass upon and handle each month, as well as the character of these differences and of the work to be done, indicate quite conclusively that there was great need of some such tribunal. The duties of the Wisconsin Commission are in fact so numerous and require so much careful analytical and scientific work in various lines, that in discussing it in this paper I shall only attempt to outline that part of the work which is involved in enforcing adequate service, reasonable rates, and sound financial methods and practices.

SERVICE.

As the services rendered by public utilities are necessities, it is of great importance that they should be adequate or up to a reasonable standard. Poor service is uneconomical, irritating and a fruitful source of dissatisfaction and complaint. It is often responsible for the greater part of the ill feeling between the public and the utility, that exists in so many places. Such service, however, can as a rule be furnished at lower cost to the utility than good service and it is in this fact that the incentive to poor service is found. To furnish inadequate service, especially when the rates charged are high enough to cover the cost of adequate service, is an unjust imposition upon the public. For the consumers are as much entitled to get what they pay for as the utilities are in charging reasonable rates for adequate service. Any other view would be unfair as well as inequitable.

In order that the utility company may be fully informed as to what is required of them in the way of service, the commission has prescribed a set of standards of adequacy for electric light and gas utilities, and conformity with these standards is in all cases enforced. In telephone, water works, street railways and steam railways, the service is not allowed to fall below a fairly definite level of efficiency.

In the case of gas, electric, water, and telephone utilities, an elaborate system of inspection and constant supervision of service matters has been instituted. The state has been divided into districts, and one traveling inspector has been assigned to each district, with the duty of testing the service of the various utilities, and incidentally of the railways, throughout his district and reporting his discoveries to the Commission.

In the case of electric utilities, the standards require a voltage sufficiently constant so that the maximum shall never be more than 6% higher than the minimum. Electric meters must be inspected at least once a year and tested at full load, half load and one-tenth load, and an error of more than 4% on any load is not permitted to continue. Incandescent lamps must be inspected and the con-

sumers must be given information as to the conditions under which their lighting installations can be used most efficiently.

The requirement for gas service is that the gas have a heating value of at least 550 B. t. u. at all times, and a monthly average of at least 600 B. t. u. This gives a grade of gas which is high enough in heating value to be satisfactory for cooking, for mantle lights or for power, and at the same time is not too high to be manufactured efficiently. The pressure at which gas is furnished to the consumer at all times must be high enough to support a column of water 1.5 in. in height; the maximum pressure must never be more than twice the minimum, and in no case must it exceed 6 in. The Commission also prescribes the amount of sulphur and sulphated hydrogen which the gas may contain. Gas meters must be periodically tested and an error of more than 2% must be corrected.

In the case of telephone service, where delays in answering calls or making connections, poor transmission, frequent calling of wrong numbers, and other similar inadequacies of service are found, the telephone companies are required to make improvements which will result in elimination of the causes of complaint. Tests during the fiscal year ending June 30, 1912, in 31 cities showed the average time required to get the operator or central out of 50 or more calls to be about 4.5 seconds, while the minimum was 3.2, and the maximum 11.7 seconds.

Inspection of water utilities covers such matters as adequacy of fire pressure, sufficiency of pressure for domestic uses, purity of water supply, accuracy of meters, and adequacy of the source of supply. Fire tests have been made in many cities, and have resulted either in the ordering of improvements in pressure or in assuring the citizens of the adequacy of their water works systems. In some cases, improvement in the sanitary quality of water has been effected through the Commission's tests, in which it has had the assistance of the state hygienic laboratory. Demands for the extension of water mains and other services are investigated, and when the conditions with respect to their cost, probable earnings, and the needs of the public are such as to warrant it, such extensions are ordered.

In the railway field, service questions involve the regularity and speed of trains, connections at junction points, the stoppage of a sufficient number of trains at the smaller stations, the proper care and maintenance of both trains and stations, the prompt and equitable distribution of cars among shippers, the equipment of the line with approved signalling and safety devices, and many other everyday matters connected with the operation of trains. Under this head also, though less directly connected with the comfort and safety of the users of railway service, is the proper protection of highway crossings, and the elimination of grade crossings. Not only are such matters as these investigated when brought to the

attention of the Commission of complaints and accidents, but the initiative is taken to a considerable extent by the Commission itself, by means of frequent inspections by its experts of roadways, bridges, rolling stock, stations and yards, etc. Unless the defects of service are so intolerable as to make an order for their elimination almost a matter of course, the determination of railway service matters involves the consideration of a large number of questions. Where train or station service is being investigated, the population to be served, the amount of business likely to arise from the improved service, the operating difficulties involved, the actual cash outlay required in making the improvement, and many similar facts are to be considered. The maintenance of passenger train schedules which will enable the railway company to meet competition between its terminals may have a bearing on the propriety of requiring the regular stoppage of a train. Another service matter which is the subject of commission supervisions is the construction of spur tracks for the accommodation of industries along railway lines. The Wisconsin law on this subject requires the Commission, on application, to order the construction of such spur track not more than three miles in length, when its construction is found to be practically indispensable to the business of the applicant, and is not unreasonably dangerous to the general public.

Special investigations are also under way, the purpose of which is to determine the effect of electrolysis upon underground water, gas, and other iron conduits. Another matter that is also just now receiving special attention is the routing, loading, headway, the number of cars and other equipment that are needed under given conditions in order to provide adequate street railway service. In these inquiries considerable progress has already been made and they are expected to lead to material improvements in the conditions.

The net result of the various measures by which the Commission seeks to keep the service of public utility corporations up to the point of adequacy has been a very marked improvement in the heating value, pressure and purity of gas in many cities in the state, the regularity of voltage with electric utilities, and general improvement in telephone service and the purity and pressure of water. Much of the result of the Commission's work in this direction does not appear on the surface because it consists in preventing deterioration of service as well as in improving poor service. It is estimated, however, that the saving from actual improvements in service has been many times as great to the people of the state as the cost to the state of this service. No money value, of course, can be set upon the fire protection and the prevention of disease which has resulted from the Commission's requirements as to pressure and purity of water, but there is reason to believe that the benefit here also has been very great.

RATES.

With respect to rates our experience varies. In many cases the rates have been found to be unreasonably high as well as unjustly discriminatory. In other instances again, though less frequently, the rates have been found to be unreasonably low. Rates that are thus too high and that under similar conditions are higher for some persons and localities than for others are harmful and against public policy. They result in unequal distribution of wealth. They mean that money is unjustly transferred from one set of pockets to another set of pockets, and that a few are enriched at the expense of the many. They retard industrial development and commercial growth, and, in the same line of business, tend to build up some at the expense of others. They also lead to results that are bad, from a rural and ethical point of view.

Rates that are too low may also be harmful. They usually stand for poor equipment and poor service. When so low as not to provide means for the proper upkeep of the plant they may even lead to the entire ruin or loss of the service. Instances where conditions of this kind prevail are met with from time to time. They are detrimental not only to those who are directly affected, but to the public as a whole. Losses from poor service may be as great as losses from rates that are too high or discriminatory.

The law provides that the rates must be reasonable. The courts have held, in substance, that under normal conditions of a plant when taken as a whole, the rates in order to be reasonable should be high enough so that the revenues therefrom are sufficient to cover reasonable amounts for the operating expenses of a plant, including depreciation thereon and interest and profit on the fair value of the property used and useful for the convenience of the public.

The sum of the operating expenses and fixed charges is thus made the legal basis for rates. The first problem of the rate maker therefore consists of determining what constitutes reasonable amounts for these expenses and charges.

The first step that is necessary in the determination of such rates is to find the fair value of the property upon which the investors are entitled to interest and profit. In this determination one is at the very outset met with conflicting opinions of all kinds, not only as to what should be included in the term "property," but as to what is meant by "fair value." Some insist that the term property includes only the physical property that is used and useful in serving the public. Others again hold that besides the physical property it also includes the cost of developing the business. There are some who argue that the fair value is represented by the original cost, and others again that it is represented by the cost of reproduction at the time of the appraisal. A careful analysis of the facts indicates that the cost of both the physical property and of the business should be included in the appraisal, and that the original cost as

well as the cost of reproduction not only of the physical property, but of the business as well, constitute evidence of value.

The original cost of the physical property includes the cost of all the land, labor, material and equipment of all kinds that are required in order to obtain a complete plant ready for operation. It also covers such overhead charges in connection therewith as organization, legal expenses, engineering and superintendence of construction, insurance and contingencies of all kinds, interest during construction period on the capital used, etc. When a plant is needed and cannot be had on better terms, the original cost may also have to include something for discounts on bonds and for promoters' expenses. In fact, the original cost of the physical property should include all necessary expenditures that were judiciously made in obtaining the plant. Before it can be effectively and economically operated, such a plant must also be provided with a working capital.

The true original cost is difficult to determine. One reason for this is that the records are too often either defective or missing. Another reason is that, even when in existence, these records contain so many irrelevant items that it is hard to pick out from the whole mass those which are material. Thus, it is often found, that construction is charged with outlays which belong in the operating and depreciation accounts. Heavy charges are sometimes also made to construction for franchises and good will values as well as for estimated future increases in values and for other reasons. To unearth the actual cost from such a conglomeration of charges as these is sometimes impossible. The probable and reasonable cost, however, is not made inaccessible by this fact, for many items can be closely estimated from the facts obtained from examinations of the present plant, its design, location, growth, character, size, the prices of labor, material and other elements which prevailed when built, and comparisons with similar plants of which the cost is known. Thus in the end a very close approximation of the actual cost of the physical property of the plant can ordinarily be obtained.

The next measure of value is obtained by determining what it would cost to reproduce the plant rather than by what the plant actually cost. In thus determining the cost of reproduction new of the plant, it is necessary to obtain complete inventories of every element that enters into such cost, as well as detailed statements of the prices at which these elements can be had, installed and shaped into an operating plant. The prices so used are the results of most careful and extended studies and compilations of market quotations and of prices at which sales were actually made. In order to avoid the abnormal effects of sudden fluctuations in such prices and to obtain results that are more nearly normal, the prices chosen may be said to represent average conditions for a considerable period, rather than the prices as of any particular date. When the elements

which are thus included in the cost cover such overhead expenses as those incurred for organization, for legal and engineering service, for superintendents of construction, for interest and the capital used in construction, for insurance and contingencies, then this cost would seem to fairly represent what the plant would actually have cost. In this case, the same as in determining the original cost, it may be necessary at times to also consider certain bond discounts and promotion expenses in arriving at the probable total cost of reproducing the plant.

Neither the original nor the reproduction cost new of a plant is a fair measure of its present cost value unless the depreciation that has taken place in the plant has been provided for and goes with the plant. Depreciation is a natural and inevitable loss of efficiency and value that takes place in practically all parts of public utility property, except perhaps land. It is caused by wear, tear and general decay; by inadequacy resulting from the failure of machinery and other parts to adequately meet increasing demands upon the plant; and by obsolescence or through the inventions and discoveries of new machinery and methods by which existing equipment has to be superseded. All of these causes are often at work in the same plant and the amount by which the property has thus been lowered in value by such depreciation at the time of the appraisal should be deducted from both the original cost and the cost of reproduction new, of the physical property and plant. The result of this is that both the original cost and cost of reproduction new are in a sense brought down to date and that the respective present cost values of the plant under both methods is obtained. The present values as thus obtained, even when the one is greater than the other, furnish good evidence as to the present fair value of the physical property.

When the value of the physical property of the corporation has finally been determined, there remains still another cost which often is legitimately a part of the investment on which reasonable returns should be permitted. This is the cost of developing a paying business. The most perfectly equipped utility plant in existence is useless if it has no customers. The acquisition of customers is a costly process. It involves not only the expense of advertising, solicitation, free experimental service, and other actual outlays, but it may include the entire amount by which the plant during the first few years of its operation fails to pay operating expenses and a reasonable return on the investment. This latter amount may be to some extent offset by exorbitant profits after the plant reaches a paying basis, or by the fact that failures to earn a return may be in part due to poor management or lack of ordinary business judgment. But when all deductions have been made for such circumstances, there will usually be found, at least for some utilities, a steadily decreasing deficit for the first few years, which is fairly chargeable to the cost of developing a paying business. This

deficit, being a large part of the cost of a successful public utility plant, is, as a rule, properly added to the present cost value of the property. It is sometimes termed "going value," but is more properly the cost of building up the business.

Just as in the case of the physical property of the corporation, the cost of the building up of the business may be ascertained by finding what it would cost under present conditions to reproduce the present business. This is done by determining from all the available data as to the amount and density of population, familiarity of the people with the use of the service in question, etc., what time would be required for a new plant to build up a paying business. The operating expenses and revenues during such period being capable of estimation, the total deficit for the period may be taken as the cost of reproduction of the business of the plant. This reproduction cost and the actual original cost of the business can then be compared, and the determination of the going value or cost of the business then depends upon the exercise of a sound judgment, based upon these two costs.

The original cost and the cost of reproduction of the plant and of its business ordinarily constitute the best evidence as to what constitutes the fair value of the property. In some instances these two costs are far apart, but in most cases they seem to approach each other quite closely. When far apart, the difference is mostly due to variations in the general price level of the elements which enter into the construction of the plant and the development of its business as between the time when the plant was first built and the time of the reproduction, although contingencies, mistakes of judgment and errors of various kinds may play important parts. The tendency today, in appraisals, seems to be to attach greater importance to the cost of reproduction than to the original cost. As to which of these factors is the most important is a matter that is greatly dependent on conditions.

When the fair value of all the property that is used and useful has thus been determined the question arises as to what constitutes reasonable amounts for interest and profit on this value, as well as for depreciation and other operating expenses. These outlays, as stated above, may be said to make up the total cost of the service.

The returns to be allowed to the investor usually consist of two elements: The ordinary rate of interest for the use of his money, and a compensation for the risk he has undergone. Both of these items vary with differences in time and conditions. Bare interest, or compensation for the use of money, is largely a question of market rates, and is determinable by a study of the investment market generally, of local conditions. The second element, or the profit to be returned to the investor as a compensation for his risk, and, to a certain extent, for the business ability and management required to look after the investment, is the resultant of many conditions, such as the location of the plant, the prospects of the municipality or region in which it is situated, the circumstances tending to make

operating costs high or low, and numerous other factors. Generally speaking, the risk is greater in a new than in an established enterprise. All of these matters when taken together indicate how far the investor is entitled to a return above ordinary interest for the mere use of his money. The best results are secured by fixing rates of return that will cause an unobstructed flow of capital into the public utility field.

Depreciation also is an element in the cost of the service and must therefore be covered by the rates charged for such services. That this is the case is quite obvious not only from the nature of the depreciation, but from ordinary business conditions. Depreciation is incurred because of the service and must therefore, like the other costs of this service, be borne by the takers. Unless it is so borne it would not be possible to obtain capital at such rates of interest as those which are accepted when it is understood that the property is to be kept up.

The operating expenses of the plants also must be audited, examined and carefully analyzed. The reason for this is that only amounts that are reasonable and necessary under the circumstances should be included in the expenses upon which rates are based. These examinations cannot safely be limited to the expenses alone, but must frequently be so extended as to cover all other records of a plant, its methods of operation, the efficiency of its management and many other factors.

When the total cost of the service has been determined, it is necessary to so classify and apportion the various items therein that proper costs per units can be obtained. Such unit costs are one of the requisites for scientific rate making.

The first apportionments in this connection consist of the allocations of the various groups which make up the total cost in accordance with their nature or the factors upon which they depend. That is, those parts of the expenses which depend on the number of consumers should be classed as consumer expenses. Those items again which depend upon the capacity of the plant or upon the demand for service, should be placed under capacity or demand expenses. Items of cost which depend on the output of the plant and which vary with such output should be classed as output expenses.

The next step consists in properly apportioning each of these three classes of expenses between the various departments of the service. That is, the total consumer expense should be borne by each department in proportion to their respective number of customers. Likewise the demand expenses should be allotted to each department in proportion to their respective demands, mostly at the time of the peak load. In the same way the output expenses should be distributed in accordance with the output for each department. The respective consumer, demand, and output cost for each department must in turn be distributed over each class of service therein, in proportion to the number of consumers, the demand and the out-

put for each of these classes. The final result will then show, for each class of the customers, the proper cost per unit of each of the three classes of expenses named. Apportionments of this kind are not, as a rule, carried down to each customer or beyond each class of customer. The reason for this is that it is usually possible to so classify the customers that the same unit cost or rate apply to each. In other words the unit costs for each class can ordinarily be made the basis for the rates of that class. These methods apply particularly to electric, gas and water companies. These separations of the expenses involve complete demand, output and consumer data for each department and for each class of service, as well as accurate and comprehensive operating and traffic statistics generally. In cases of joint operation it also means a separation of the common expenses between the utilities involved. In addition to this it is often necessary to study transmission losses, the saturation of the territory, the nature of the uses to which the service is put, whether the service is metered or not, wastes and losses of all kinds, the adequacy of the service and numerous other facts and conditions. In this way unit costs are developed which become proper and safe bases for rates.

In the railway service, the expenses and fixed charges are first apportioned between passenger and freight traffic. When the total cost of the freight traffic has thus been ascertained, it is further apportioned as between the cost of handling the freight at the stations and the cost of moving it between stations. The latter apportionments are necessary because the terminal cost depends on the number of tons handled, while the movement cost depends on the length of the haul. With these costs, together with other necessary operating and traffic statistics at hand, it is possible to determine, for the average loading per car, the gross and net cost per ton of the terminal expenses and the gross and net cost per ton per mile of haul of the movement expenses. These costs per units under average loading are further modified by the effect upon these costs of the respective loadings per car, by the effect of the weight that is and should be given to the value of the articles in rate making, and by the effect of such differences in the cost as are usually found between local and through transportation; the figures or unit costs so obtained are certain to be of the greatest aid in establishing just and reasonable rates. In fact, these figures are indispensable in rate making, even in cases where they may have to be further modified because of competitive and commercial conditions.

The loading per car greatly affects the cost per unit of transportation. One reason for this is that switching and other terminal expenses per car are about as great for a car that is lightly loaded as for a car that carries a heavy load. Another reason is that in moving the freight between the stations, the cost per ton is as great for the car itself as for the freight in the car, and that in light loading, this cost of moving the car alone must be borne by a

smaller quantity of articles or pay freight, while under heavy loading this cost per car alone is distributed over larger quantities of articles. Owing to these facts, the net costs per unit are often several times as great under light as under heavy loading.

Local or way freight trains, owing to the frequent stops that are necessary in handling traffic from station to station, make less mileage than trains which handle through traffic. They also, as a rule, carry lighter loads. The result of this is that the costs per unit of traffic are often somewhat greater for local than for through traffic.

The value of the articles is a recognized element in rate-making. While it costs no more, when other conditions are the same, to transport more costly than cheaper goods, the former involve greater risks, and can bear much higher charges. Rates that cover their proportion of the operating expenses, including interest and profit, at the rate of, say, 30%, may be less of a burden on high grade traffic than is the case of rates which cover their share of the operating expenses, including interest and profit, at the rate of, say, only 3% for low grade traffic. To charge higher rates for more costly than for cheaper commodities is in line with public interest, for it is only at lower than average rates that many low grade materials will move at all.

Competitive and commercial conditions must also be recognized. While, owing to consolidations, active competition is less important than formerly, it is yet a force that must receive consideration in rate-making. To meet conditions of this nature, it is often best for all concerned to accept competitive business at rates which are high enough to cover the additional cost of handling such traffic, plus a small amount above this for fixed charges, provided, of course, that such low rates can be put into effect without unjust discrimination in other respects.

Few subjects are more complex than these which involve rates that are equitable and just to all concerned, and few are also of greater importance to the public. Rate schedules under which each department and each customer are made to bear their just share of the total cost of the services do away with unjust discrimination in rates. They provide like rates for like services under similar conditions. This is of special importance in the transportation field, and in the case of power rates, wherever slight advantages or disadvantages stand for success or failure, not only among industrial enterprises, but among localities as well. The value to the public of the elimination of rates that are too high and of discriminatory practices of this kind and of the establishment of equal conditions in these respects, is many times as great each year as the cost of maintaining the commission.

UNIFORM ACCOUNTS AND REPORTS.

Whether the principles which govern public utility regulation are violated, is largely a question of facts. It is in order to find the

facts that the service of such utilities is inspected and other activities investigated. To this end also it is necessary that their accounts and records should be kept on some basis that is uniform, that discloses the integrity of the various items, and under which they are so classified and arranged that they may be subjected to the proper analyses. In fact, effective regulation is largely, if not entirely, dependent upon the degree to which the actual facts involved are known and understood.

The Wisconsin law provides that every public utility shall keep such uniform accounts and records of all the business transacted and make such reports thereon as may be required by the Commission. In accordance with this, the Commission has prescribed classifications and forms of accounts, records and reports for each class of utilities of the same kind. These classifications and forms are much more simple for small than for larger utilities. They have now been in effect for some years and have brought good results.

Accounts so kept and reports so made enable comparisons of like facts for the same utility from time to time as well as between different utilities. They show all changes that take place in the various items and enable one to judge of their integrity. They disclose whether plants are efficiently operated and point out ways of improvements in the operation. They enable the various items to be grouped with reference to the causes from which they emanate as well as in accordance with proper units upon which for one purpose or another they may have to be apportioned. They disclose maximum, minimum, average and normal costs per unit, as well as other elements that are of the greatest importance. In fact no statistical compilations and no unit costs could be secured that would be of real value unless the financial and the operating reports were compiled upon a uniform plan of this kind.

Even when so kept, the accounts and reports often require careful checking and auditing. No important rate case, for instance, is passed upon without the examination of books and records. The annual reports are also carefully checked and verified. As about 1,100 such reports have to be gone over each year, this is a task that requires the services of several persons. It is labor well expended, however, for without it, even under the uniform system, many reports would be misleading.

Where the utility, for some reason, is unable to comply with the uniform system and to prepare acceptable reports, the Commission holds itself in readiness to render the necessary assistance. For this purpose it employs several accountants who fully understand their duties. In some instances the difficulties can be straightened out by only slight changes in the records and forms. In other cases again it is necessary to provide and install entirely new systems.

In fact, the work of designing complete accounting systems is now one of the very important services rendered by this Com-

mission. Such demand has been made for accounting aid that it is now necessary for several men to give their entire time to the work. Applications for assistance are filed and are disposed of as rapidly as possible. In almost every one of these instances it is necessary for the representative of the accounting department to make a personal investigation of the books and records of the utility. If only slight changes are needed, it may be possible to bring about the desired results by introducing certain special forms, such as a time card, material slip, voucher check, etc. Where a completely revised system seems necessary, the Commission's accountant on his return to the Commission's office will design a system of accounts adapted to the needs of that particular utility. These systems of records and forms are kept on file in readiness for distribution to utilities seeking suggestions on accounts and forms. About 100 special forms have been designed up to date. The supplying of these blue print forms has apparently been of considerable help to the utilities. About 110 utilities have received blue prints so far, and many of these have installed forms corresponding to the prints.

During the year from January 1, 1912, to January 1, 1913, the Commission gave special accounting assistance to 30 public utilities. For 12 of these 30 complete systems were designed and installed and are now in operation. Some of the utilities called for special assistance that did not require installing a system, while for others systems are in process of preparation. There are at the present time a number of utilities on a waiting list that will be attended to in the near future. Where systems have been put into operation, there has been a marked improvement in reports and it is of course evident that the improved accounting systems will greatly facilitate securing information for a rate case that might arise in the future.

One problem that has been very hard to handle is the adjustment of municipal reports. It is the purpose of the Uniform Classification to make utilities of the same class, regardless of form or ownership, comparable with one another. In bringing the accounting procedure of municipal utilities into line with these uniform rules, many more obstacles and difficulties have been met with than in the case of private plants.

The Commission has taken the attitude that a municipal plant should report earnings for services furnished by one department to another in the same way as though the utility stood apart from the general city administration. Thus "Hydrant Rentals" should be reported as an earning to a municipal plant, even though, as some municipal clerks have said, "It is only taking something from one pocket and putting it in the other." The fact remains, that the utility has furnished the service and has *earned* a return for it, regardless of whether or not it actually has any more cash on hand to show for it. Unless such interdepartmental transactions are

reported, no fair comparisons can be made between privately and municipally owned plants.

The fault does not necessarily lie with the administration of the municipal utilities themselves, but should rather be attributed to the weaknesses in the entire accounting method which prevails in many of our cities. It is a difficult task to accomplish any permanent advancement or improvement in the accounting procedure of the municipal utility, when the entire municipal system coupled up with that utility's administration may be unscientific and inadequate. Just as soon as any attempt is made to regulate the utility end of it, the necessity of reforming the entire municipal accounting procedure becomes obvious. If it is the city's practice to cover all transactions with the General Fund and to make little or no attempt to show operations of departments as separate activities, it is difficult to require that the procedure affecting the utility be revised without adjusting the other operations so that they are harmonious throughout.

The Commission has pointed out to municipal plants the importance of segregating their transactions, as far as possible, from general city business. It is to be hoped that cooperation with other state departments will be able to arouse the cities to realize the inadequacy of much of the present municipal accounting and to institute reforms in municipal accounts which will show separately the operations of each department of the city.

It is interesting to note in this connection that much the greater share of special accounting assistance that has been rendered during the past calendar year, was for municipally owned utilities. In fact, out of the thirty utilities assisted, twenty-three were single municipal plants and eleven were joint municipal utilities. The majority of the applications for help now awaiting consideration are from municipal utilities. It seems fair to conclude, from the condition of the annual reports received and from the appeals for help that have been received, that the municipal plants need the assistance of a state commission.

CAPITALIZATION.

Another important duty of the Commission is to supervise the issuance of securities. Under the Wisconsin law, public utilities cannot issue stocks and bonds without a certificate of authorization from the Commission, and they can be issued only for cash, property or services. If the payment is in property or services, an appraisal of their value is made by the Commission, so that in no case will the security issues exceed in amount the value paid into the corporation. The Commission also takes care that the bonds shall not constitute an unduly large proportion of the security issue. The purpose of all this is to establish as close relations as possible between the investment and the securities issued, and also to keep the management of the property in the hands of those financially interested in it.

The extent to which the Wisconsin Commission has exercised control over stock and bond issues of Wisconsin public service corporations, may be indicated by a statement showing the security issues authorized by it. The applications for authority to issue stocks and bonds, disposed of in that one year, number 148. Ten more were still pending on June 30. Issues of securities were authorized during the fiscal year ending June 30, 1912, amounting to the following figures:

Stock	\$ 5,132,678.00
Bond	61,330,900.00
Equipment, Trust Certificate.....	10,055,000.00
Notes	1,097,166.66
	\$77,615,744.66

When the total amount of such authorizations from the passage of the public utilities law in 1907 down through June 30, 1912, is considered, we find total stocks authorized amounting to about \$212,000,000, and total bonds authorized (including notes) amounting to about \$574,000,000, or a grand total of \$786,000,000 in stocks and bonds. These figures represent one state alone. They throw a great deal of light on the enormous amounts of such securities that are issued and floated annually in this country.

The evils of overcapitalization of public utilities are many. It makes the securities a speculative instead of an investment proposition. It contributes toward keeping the small local investor out of the public utility field, because the small investor will not risk his capital unless the securities offered to him are not only placed on a safe basis but are fairly demonstrated by some trustworthy authority to be so placed. This exclusion of the local investor from the public utility field is a great loss both to the investor and to the public utility. It deprives the former of a better paying investment than the savings bank, and as to the latter, it prevents that community of interest and harmonious relation between the utility and its customers which is likely to be present if the customers have a financial interest in the utility. This point, though generally overlooked, is exceedingly important, especially under the conditions of public sentiment toward public utilities that are generally prevalent today. A fairly general local holding of public utility securities, would go farther in preventing the unpleasant and often expensive controversies that now so frequently arise between utilities and their patrons, than almost anything else that can be mentioned.

Furthermore, since overcapitalization increases the risk to investors, it must also tend to increase the rate of return which must be allowed on their investment, for as has already been explained, the element of risk is of much importance in determining the reasonable rate of return. That many utilities, because of their finan-

cial methods, find it difficult to obtain needed funds at reasonable rates of interest, is only too well known, and the result is an economic waste that could easily be avoided. Overcapitalization also tends, in the absence of strict regulation of rates, to keep the utilities' rates higher than they would otherwise be, for strong pressure is exerted upon the management to pay dividends on the inflated capitalization, and reductions in rates are vigorously opposed by the security holders. Another result of this pressure is that earnings, which should be used to provide for repairs and depreciation, are often paid out to the security holders in interest and dividends, and the service of the plant naturally deteriorates. Failure to provide needed extensions to the plants is another important result of this policy.

Overcapitalization also has a bad moral effect on officers, employes and the public, because it represents both efforts and training in receiving something for nothing. It is often a means for covering up excessive earnings and an excuse for bad service.

Another evil fostered by the unlimited right to issue securities, is the unnecessary and economically unwise consolidation of public utility plants under one management. Consolidations of operating properties are sometimes a very prudent and economical move, but there are times when consolidations are effected with a view solely to profit on the part of those promoting the consolidation, and it is schemes such as this that are now referred to. The opportunity to combine two corporations and issue securities exceeding the combined value of their properties, is so tempting that, in the absence of regulation of security issues, public utility managers have often availed themselves of it in the past, much to the detriment of the public.

All reasonable expenditures in promoting, financing and constructing the plant and developing its business are proper subjects of capitalization. If such items only are capitalized, then it would also follow that the outstanding securities would agree quite closely with the amounts invested and with the amount upon which investors are entitled to reasonable returns for interest and profit, at least under normal conditions. Utilities financed upon this basis would ordinarily, or where no unusual situations are encountered, become safe investment propositions. For their securities would be backed up by actual investments as well as by earning power, and should be nearly as well secured and as easily saleable, as municipal bonds. This is a situation, however, that will not be generally attained for some time to come, and this for the reason that the utilities are ordinarily so overcapitalized at the time regulation goes into effect that, except for new utilities and for extensions to existing utilities, considerable time is required to bring about the proper relation between the investment on the one hand and its capitalization on the other.

As the utilities are managed or operated by the stockholders or

their representatives, it is of the utmost importance that there should be a proper relation between the stock and bond issues by which the investment is represented. When, as is often the case, the bonds represent practically the entire cost of the plant and its business, and the stock little or nothing in the way of actual investment, it necessarily follows that the business may be managed and the operations controlled by those who have no actual investments of their own to look after, and who may therefore have more to gain from a reckless than from a proper and honest management. Thus the best interests of such stockholders may be found in paying dividends on their stock whether earned or not. In order that they may be able to pay such dividend they may withhold earnings from necessary repairs or renewals; and for the same purpose they may even borrow money. Where stockholders have interests in the form of actual investment to protect, and which interests can be taken to cover liabilities, such practices are naturally much rarer than where they have little or nothing to lose. In the former case the stockholders are also less likely to pursue short sighted policies with respect to rates and service than in the latter. Rates that are too high or unjustly discriminatory and service that is below a fair standard may result in immediate increases in net revenues, even though in the long run they may stand for loss of business and for lack of developments in the same. Immediate increases in earnings, therefore, especially when the real situation can be kept in the dark, may enable dividends to be paid, and on the strength thereof the stock may also be sold at much higher than fair prices. Such practices are bad for the customer, the public and the investor. They are common enough almost everywhere to demand legislative attention.

One of the most effective means, therefore, to bring about honesty and effectiveness in managements is perhaps the one that has been suggested, namely this, that no stock should be issued which does not represent outlays either in cash or property or in performing needed service. Experience teaches that properties and businesses are, as a rule, much better managed by owners than by those who are not owners. The proportion of the equities in a plant that should thus be represented by stock is a matter that must largely depend on the circumstances in each particular case. Ordinarily, however, it should not be much less than one-third.

Applications for security issues must be accompanied by detailed statements showing the purposes for which the issues are desired as well as statements showing the assets and liabilities and the earnings and expenses of the plant. These statements are closely examined by the Commission. When the issues are made for other property than cash, such property is also carefully appraised. In addition to this the plants are also required to make subsequent reports upon how the securities issues were exchanged or the proceeds therefrom expended. These reports are also examined and

verified by the Commission. In this and other ways security issues are closely regulated.

Economy, theory and public policy demands that in cases where monopoly conditions prevail there should be close relation between the amounts judiciously invested and the securities by which this investment is represented. Any other course in the public utility field is, in the long run, almost certain to result in poorer service to their customers and in losses to their investors. In other words, the gains which come to the few from improper financial practices are inequitable and in the end are also certain to have to be unjustly borne by the public.

REGULATION OF CAPITAL EXPENSES.

There is one more field in which the Commission has an important function in promoting the highest efficiency and lowest cost of public utility service. This is in the prevention of duplication and waste in the establishment and extension of both railway and municipal utility plants. It is recognized by the railroad and public utility laws of Wisconsin that public service corporations are in their nature monopolies, and that the interests of the public are best conserved by protecting monopoly in these industries and at the same time supervising and regulating them in the public interest. To carry out this purpose, competition among public service companies in the establishment of new lines and plants is prohibited except under such conditions as make its existence a benefit to the public.

In the case of railway companies, the Wisconsin law provides that before new lines are built or extensions are made, a certificate must be obtained from the Commission stating that public convenience and necessity require the construction of the new line. The problem here is somewhat different than in the case of most municipal utilities, for no two railways serve exactly the same territory, and although the terminals and some of the intermediate stations may be the same, it may well be that the remainder of the territory traversed is so badly in need of railway facilities that the authorization of the entire line may be warranted. In such cases the amount of population, its tendencies as to growth and industry, the availability of existing facilities, and many similar facts are material and require careful consideration. It is also important to determine whether the new line is likely to be capable of profitable operation, for a railway line which cannot make expenses is likely to be more of a burden than a benefit to the community.

In the case of municipal utilities, this object is accomplished through the use of the indeterminate permit. By virtue of the state's constitutional power to amend or repeal franchises, the state of Wisconsin has amended every municipal franchise so as to constitute an indeterminate permit, which is merely a substitution of the provisions of the public utility law itself with regard to rates,

service, and other matters, for the extinguished franchise. Without the consent of the Commission, no competing utility company is permitted to enter a territory served by a corporation operating under an indeterminate permit, but whenever the Commission finds that public convenience and necessity require the admission of such competition, a certificate so stating may be issued to a new utility and the latter is authorized to enter the field. The duration of the indeterminate permit is limited only by the right of the municipality to take over the utility's property at any time, at a valuation fixed by the Commission.

The indeterminate permit thus recognizes the monopolistic character of the public utility business, and provides for continuance of the monopoly, but at the same time safeguards the public by admitting competition when the public interest requires it. Most local utilities are of such a character that duplication of plants and equipment necessarily involves a waste. Two pole and wire lines, for instance, or two sets of water mains in a single street are obviously more expensive than one line or main adequate to serve the entire street. The same is in general true of the power or pumping plant, although there are numerous items of expenditure that are not necessarily made wasteful by duplication. Not only is there expense connected with duplication of plants, but considerable public inconvenience also results. Streets must be torn up oftener to get at mains and services, and duplication of poles and wires results in unsightly and more or less dangerous obstructions. In the telephone business, the service itself is rendered less efficient by the existence of two companies, unless physical connection between them is required, since the natural interdependence of subscribers on one another for use of their equipment requires that each telephone be capable of connection with each other telephone in the city if the service is to be as valuable as possible to the public.

It is therefore only in very exceptional cases that a commission could be justified in admitting competition among public utilities in a municipality, for the waste in equipment and other inconveniences generally more than offset all benefits to be derived. It may sometimes happen, however, that a plant is in such poor physical condition, and at the same time is so heavily overcapitalized, that it is unable either to give good service, or to obtain funds for making improvements. Under such conditions or others of a similar nature, it is conceivable that public convenience and necessity might require the admission of a competing utility.

By keeping fairly close rein on the investment of capital where another investment has already been made for the same purpose, and at the same time permitting such extensions and even duplication as will result in the greatest development of profitable business and the widest diffusion of needed services among the public, the Commission's regulation of capital expenditures is capable of

producing very beneficial results to investors and a permanent advantage to the consuming public.

It appears from what has thus been said that there is a widespread need for effective regulation of the services, rates and financial practices of public utilities, and that such regulation, when fair, is in line with public policy; that such regulation should be largely governed by existing conditions, and that it should be flexible enough to properly adjust its activities to such conditions; that it is more concerned with preventing future wrongs than with redressing past offences; that the wrongs it is designed to prevent are comparatively small when considered individually but large when taken in the aggregate; and that since many of the individual wrongs are small, it is of the greatest importance that some method should be devised under which they can be adjusted at the lowest possible costs to those who are thus harmed.

The facts thus presented also throw a great deal of light upon the powers and the equipment of various kinds that are needed for effective regulation by those tribunals to whom this work is entrusted.

We thus find that the work of regulation is of such a character that it does not fit in with the work of the courts. Courts deal with what has happened rather than with what may happen. They redress wrongs already committed and the precedents they establish serve the same purpose. They are not prescribing, establishing and enforcing rates and regulations to be complied with in the future. Not being equipped with trained staffs for this purpose they are not in position to gather the facts that are required for intelligent regulation nor to exercise the necessary supervision in connection therewith. Their methods of procedure are slow, formal, and costly to the litigants. They are adjusted to work of a different character than that which is involved in the regulation of public utilities.

It also seems that franchise and other legal provisions of the kind also fall short of providing such regulation as is needed. Provisions of this sort are seldom based on actual conditions, and this largely for the reason that the data needed for this purpose are not available. Fair rates and adequate services can only be determined by such processes as those outlined above and this work can hardly be continuously carried on except by bodies which are organized for this purpose. Conditions by which such regulation must largely be governed are also constantly changing. Rates, for instance, which are fair when put into effect may be unjust shortly thereafter or long before franchise and other provisions expire. This is also true of service and other regulations. Methods of regulation which are inflexible and which remain the same regardless of conditions are more likely to be harmful than beneficial. In such matters it is seldom safe to rely on guesses as to

future conditions. Franchises and other laws of this sort are also as a rule ineffective for lack of proper enforcement.

Judge McPherson of the Federal Court in his discussion in the Des Moines Water Case, September 16, 1911 (see 192 Federal 194-195), comments upon franchise and court regulation in the following language:

"This is a case involving the validity of an ordinance of the city of Des Moines fixing water rates. The water company filed a bill in equity to enjoin enforcement of that ordinance, alleging that the same is invalid because unremunerative as to the rates thus fixed, as well as for other reasons, to be noticed in this opinion. It is now more than three years since the passage of this ordinance. This case illustrates the evil in connection with the fixing of rates by municipalities to govern public utility corporations. Neither party is properly chargeable with any dereliction and yet the fact remains that by the time this case is decided by an appellate court at least four years will have elapsed from the passage of the ordinance until the matter is put at rest by the courts. It is utterly impossible for a court to hear all cases similar to this, which require from two to three months to hear the evidence, after the issues are formed. If this court were to do nothing else it could not personally hear all such cases. The Supreme Court of the United States has said that the seemly and orderly way to determine these matters is to refer them to a master in Chancery, to take the evidence and make reports on which the courts can act." . . .

"The present expensive chaos should be brought to an end. It is known by all informed men that city councils necessarily adopt rates with but little or no investigation as to what rates ought to be fixed. The result is that we have ordinances fixing rates based upon but little intelligent effort for the ascertainment of the facts. Some of the states, like New York, Massachusetts and Wisconsin, have state commissions of competent men who give public hearings and who do nothing behind doors, nor in secrecy—a commission with no member interested as a taxpayer of the city, and with no member subject to influences other than the ascertainment of the truth and the facts. Rates are thus fixed with which most fair-minded people are ready to acquiesce. It is strange that we have no such legislation and no such commissions in Iowa."

It is because effective regulation of public utilities cannot be had either from the courts or from franchise and other provisions of this kind and because competition is also ineffective for this purpose, that people in this country are turning to the public utility commissions for relief. From such experiences as we have so far had in this matter, it also seems that such commissions, when provided with such power and such equipment as those conferred by

such laws as the public utility law of Wisconsin and by such bills as the one now before you are the very tribunals who can best meet this demand.

Public utility commissions of this kind are established and organized for the very purposes of such regulation. They are therefore provided with the employes and other facilities that are needed for the establishing of reasonable rates and standards of service and of seeing to it that these rates and standards are actually complied with. They are also required and equipped to perform much other work in the same line. In addition to that they have all the power that is necessary to carry their work into effect. The inspection and supervisory power which such commissions have are among the most important features of the work. It seems to contribute more towards establishing equitable and fair conditions in the public utility field than almost anything else.

Utility commissions of this kind also seem to be about the only tribunals who, in their work of regulation, are in position to adequately consider the interests of all who are affected thereby. They can see to it that private consumers are charged no more for the service than is reasonable under the circumstances; that the returns of the utilities are limited to the amounts which will bring the necessary capital into the field; that the investors are not loaded up with securities which are not backed up by amounts judiciously invested; and that the public as a whole is not made to suffer for lack of necessary development and extensions of the service or by any other acts that are not in line with public policy.

Such commissions being appointed for a long term of years, and charged with important duties of a highly technical character are also likely to be taken almost entirely out of politics. This means that politics alone will not shape their policies; that irrelevant and disturbing influences of all kinds are gradually being eliminated from their work, and that they are able to adopt sound policies and to determine the question before them on their merits. The importance of all this is much greater than is generally realized.

There is perhaps no more important feature of commission regulation than the fact that it affords an inexpensive and, for the most part, prompt remedy for such grievances as are constantly arising between individuals and the public on one hand and utilities on the other. In Wisconsin, for instance, by far the greater proportion of the complaints of all kinds are settled either through correspondence or in informal conferences. All the aggrieved party does in most of these cases is to write the facts to the Commission. The Commission thereupon investigates the matter. In fact it does practically all the work that is necessary for settlement of the same upon the facts.

The utilities themselves, especially the smaller ones, also take advantage of these opportunities. They are constantly submitting to the Commission matters which need adjustment. They are also

regularly availing themselves of the engineering, statistical, accounting and other data collected and kept on file by the Commission. Such data is necessary to the Commission in its work. It is also of the greatest value to the utilities and the public. It is a sort of a storehouse of facts upon which all can draw and which is constantly utilized. It assists in settling disputes and is as often a means of preventing disputes.

While state regulation through commissions in the form in which it exists in Wisconsin and a few other states dates back only a few years, it has probably been in existence long enough so that the experience under it will disclose whether it fairly meets the purposes for which it was created and whether it yields results that are in line with public policy. On the one hand it can be said that regulation has resulted in better service at lower rates and that it had done away with most forms of unjust discriminations. Frequent and thorough inspection of the service, detailed and complete appraisals of the property, the institution of uniform accounting systems and report forms, the determination of the cost of the service both as a whole and by departments, the development of scientific and equitable systems of rate making and the supervision of security issues and capital expenditures cannot be without value. The direct benefits thereof to the public have been great. These benefits have also been obtained without injustice to the utilities or their owners. The indirect benefits therefrom, such as accrue from the facts brought to light and published in all work of this kind are also important. Such facts have become the basis for demands for improvements in the conditions as well as the means by which unjust suspicion and unfair agitation have been allayed. Publicity is always an important factor in all matters affecting public interests. This system of regulation has also in a measure taken the utilities out of local politics.

On the other hand, it must be admitted that it has not brought the millennium. Many are much more critical of the service and exacting in their demands in this respect than they were before regulation was ushered in. Others again are much disappointed because the reductions in rates have not been greater and because the values placed on the plants have not been lower than those so far ordered. City officials object because the control of the utilities has in a measure been taken away from them, and have set up an agitation for local control. While this is based on personal rather than on public interest, it is nevertheless present. Some are also more or less disgruntled because the cases they may have started, cannot be decided immediately, or because they cannot always be safely passed upon until the plants have been appraised, their accounts audited, their other records checked, the hearings held and the reports upon the law and the facts prepared. It is true that the first rate case against a utility, because of the immense amount of work involved, may require considerable time before it can be de-

cided, but it is also a fact that this time is constantly being shortened as the work becomes better established, the needed information obtained and firmer foundations laid. Most of the complaints against regulation of the kind in question here are without foundation. They are much more frequently actuated by personal or political interests than by questions of public policy.

DISCUSSION.

President Reichmann: There is no subject, I think, which is entitled to more careful consideration and study than that of the regulation of public utilities in our various states and municipalities, and I might say in the United States. It calls for the deepest thought from men of the greatest depth, who have a keen sense of justice,—men who will know how to properly protect and preserve the interests of the public at large, and at the same time see that the people who have their money invested in the various enterprises receive the justice to which they are entitled.

Mr. Erickson is one of the men who, I think, can see all the different angles of this subject, and he is probably one of the greatest men in his line of work in the United States.

Bion J. Arnold, M. W. S. E.: The author seems to have laid down in his paper the fundamentals of public regulation of public utilities, which fundamentals are recognized by those who have given the subject any considerable study. He has laid them down so well in a general way that there is hardly any room for discussion as to their correctness, and certainly no one is better qualified to lay them down than the author, or the Commission to which he belongs. We might, however, elaborate upon certain things that he has laid down.

This Commission, by the way, was one of the first to be organized in the United States, and in a state which was considered extremely radical toward corporations. Its then governor, now senator, is not known as a man who is ultra-conservative toward corporations, and therefore it was expected that the carrying out of a law which he might have been instrumental in framing might be more or less radical. But I am glad to say, and I am sure others will say and do say, that instead of that law having been so construed by the Commission which was then appointed, it has been most liberally construed toward those who expected to be more or less temporarily injured by the installation of such a utility Commission in the State of Wisconsin. This Commission has looked at the questions put before it in a very broad way, and has been brave enough and broad enough to do justice to the corporation when the corporation really was entitled to it, and the corporation is often entitled to it when it does not get it, due to the extreme radicalism which has prevailed in the past in different parts of the United States. That condition has been largely brought into the community through the improper actions of the corporations them-

selves. Fortunately, it does not exist to such a great extent today. The point I am trying to make clear is that a public service commission, appointed in what was then supposed to be a radical state, was sufficiently broad to take up these questions and handle them in the admirable manner in which this Commission did handle them, and that fact established confidence in the minds of those who had been previously skeptical regarding the public service commission question. Such is the Commission to which Mr. Erickson belongs.

This Commission has set a precedent in many cases which has been followed by other commissions and those having to do with public questions throughout the country. I do not live in Wisconsin and have no interests in that state, although at one time, prior to the organization of this Commission, I did have some interests there, but I have been informed that the public utility companies look at this Commission with a great deal of respect and as a court of last resort, as it were, although it really is not; the courts finally determine questions, I suppose, as they do in most states. But it is practically a court of last resort to which the companies can go with their troubles, have them analyzed, and be sure of a just and fair decision. The public likewise goes to this Commission, and while, as the author has said, the public does not always come away entirely satisfied—neither do the companies—yet on the whole the decisions have been just and acceptable, and there is no reason to complain of the decisions which have been made. In fact, this Commission, as I have said before, has established precedents that have been adopted throughout the country.

I was particularly impressed with the point brought out in the paper that apparently the municipally-owned and operated plants require at the present time greater regulation and greater systematization than do the private ones, presumably because the private ones have been well regulated by this Commission for a few years now, and the Commission is just getting into the municipal plants. We all know, however, that the records of municipally-owned and operated plants are not as a rule kept in such a way as to invite close analysis. I mean by this that there is not necessarily any intent to deceive nor any intent to have things wrong, but they do not classify their accounts in such a way as do private utilities and in such a way that they can be analyzed in comparison with private utilities. Therefore, it is not strange the author has found that during the past year out of thirty companies which have been analyzed as to the fairness of their rates, twenty-three were municipal plants and eleven were semi-public plants. In other words, the most of them now requiring attention are either municipally-owned plants or semi-municipally-controlled plants.

The question of capitalization is quite a serious one in this country at the present time, and this is the question that is usually most difficult to solve, either by the corporation or by the municipal-

ity which is endeavoring to regulate the corporation. I, as well as others, have given that subject considerable attention, and I have, at least in my own judgment, worked out a plan which to me seems satisfactory and works toward getting rid of the present excessive capitalization of many of these companies, and in a manner which I believe is fair to the public and fair to the companies. I do not mean to say that I have evolved it entirely alone, but the plan has been evolved and given considerable attention in the past ten years, and I have had the pleasure of having a part in the solution of it. I have analyzed many cases. Sometimes I have been on one side and sometimes on the other, sometimes representing both sides, and I have always pursued the same policy. It is immaterial which side I have been on, or whether I have been on both sides. I have always endeavored to find a value of the property which seemed fair, all things considered, that the municipality and the corporation ought to agree upon as a capitalization with which to start anew. That capitalization almost always contained a certain amount of intangible value which was usually due to the past experience of the company, in taking in other companies in the way of consolidation, a certain amount of promoters' profits, discount on securities, legal expenses, obsolete property, and all those incidental expenses which go into the originating and incorporating of a company and in consolidating various companies. I will not attempt to enumerate them because they are many.

Very often a franchise value, due to the fact that the franchise which the company owns has not yet expired, must be included; and if you are going to agree upon a valuation of a company you must take into consideration not only the value of the physical property constituting the plant at the time, that is, the present value or the depreciated value, but you presumably must add, and usually do add, some franchise value. If it is clearly admitted that the franchise has a given life, its value is easily computed by those who have had sufficient experience to understand the subject.

Then the argument generally comes up as to whether there should be any franchise value, as to whether any of these intangible values should be admitted. The public usually takes the position that no such values should be admitted; that the company has been so managed in the past that it has charged excessive dividends, *i. e.*, taken them and put them in its pocket, and therefore it should not be entitled to any of these intangible values and the physical property basis only should be taken to start with. That hypothesis is not absolutely incorrect in all cases. It might be correct in some cases, but it is not a principle we can tie to, or to apply in all cases. Consequently, intangible value almost always enters into the problem. Therefore, if we get a capitalization which can be agreed upon between the municipality and the company to start with, even though there is some intangible value in it, we should determine how much of it there is, and in any resettlement franchise or set-

tlement franchise we should make provision for the decapitalization of that intangible value. That is, the profits of the company should be devoted, first, to the paying of operating expenses, and second, to a reasonable return upon the agreed capitalization, which includes the physical value and some intangible value. Then there should be an amortization fund established, at a low enough annual rate so that it will not be impossible for the company to give adequate service and also earn its agreed return upon its capital plus a percentage of the net, if that shall be agreed, without raising the fare. In other words, the amortization should be at so low a rate per annum that it will not unjustly affect the public or the company.

Now, the questions are to find what rate of return the company shall have upon its agreed capitalization, and what its proper amortization rate should be. There are other elements one might put in, but these are two fundamentals. If a certain percentage of the gross receipts or of the net profits (if you can get them properly computed) be put into this amortization fund and allowed to grow, this fund will gradually retire the intangible value. So there will finally come a time when the entire intangible value can be handed back to the company,—or it can be handed back yearly, if you choose, to the company,—and with a proper interest return on it so long as it is allowed to remain in the capitalization, and eventually if the capitalization of the company is reduced in proportion as this amortization fund is increased, there will come a time when the value of the physical property producing the service will equal the capitalization of the company. The citizens should then be required to pay only a rate of fare which will give a fair return upon the value of the physical property producing the service. There I claim the capitalization should be kept if the plant is to be privately owned. The public should pay a rate which will pay the company a proper return, and the rest should go to the betterment of the property and for the benefit of the public. The municipality should not make a profit on a public utility. If profits can be made by the city out of public utilities, these profits, instead of being paid into the city treasury, should be devoted to bettering the service, until the service is adequate, and after this these profits should be devoted to the reduction of fares or rates.

Edward W. Bemis: I cannot quite agree with Mr. Arnold that the Wisconsin Commission was the first important commission, although it was first, probably, in the West, at least the first in the West dealing with municipal utilities. In 1885 the Massachusetts Gas and Electric Light Commission was created, and since 1894 it has had entire jurisdiction of the issue of securities. Its volumes of reports have been a great source of suggestion, information, and light throughout the country. As regards railroad commissions, I do not know whether Massachusetts, with her commission in 1879, took the lead or not, but she was one of the first.

The Wisconsin Commission has certainly marked a great epoch

in the development of the commission idea, especially with reference to municipal utilities. It has entered upon a field, rather unique in some respects, at least it has been a pioneer in that direction, and it may be well to note what those features are, whether we altogether agree with them or not.

It has entered upon the control of accounting and publicity of accounts and the securing of comparable figures as between one plant and another of the same kind. That plan is not really novel among commissions; it has been in vogue, to a considerable degree in Massachusetts at least, for many years. It may be carried a little farther today in Wisconsin than in many states. It is probably a work with which we all agree most heartily,—one that cannot be carried too far to suit us. We need all the accounting and all the publicity and all the comparative data that can be secured both as to privately-owned and municipally-owned undertakings.

The Wisconsin Commission, moreover, has, as has been so well presented tonight, developed the control of the service of utilities both public and private, and that idea, again, while perhaps not unique, has been carried forward very successfully and is one, I am sure, which has only good in it and the farther it can be carried the better.

The Commission has also developed and carried forward the idea of amicable relations between the consumer and the utility and settled a great many questions, as it were, out of court, which is characteristic of most successful commissions, and is also a matter which we can all endorse, I am sure.

Mention has been made of the Commission's controlling capitalization. We are anxious for as much light as we can get upon the history of that movement in Wisconsin. I am not thoroughly informed upon it myself, although I have had occasion to read a great many of the reports of the Commission. Probably the author can enlighten us, a little later in the evening, as to whether the Commission was given this power of control of capitalization at the beginning of its career or only recently. I have been informed that perhaps four years elapsed after it began to regulate rates and service before it began to regulate capitalization. Some in Wisconsin who are close students of the question have stated that it is a very good thing to postpone the control of capitalization for a while, until a commission has thoroughly developed its corps of engineers and accountants so that it can value these properties with great care and accuracy. Some commissions are given power of control of capitalization at the start, perhaps before they are equipped to handle it, and the question will arise from Wisconsin's experience as to what can be learned in that direction.

In that same connection it would be interesting to learn what happens in that state when a company is seeking to issue securities for actual, tangible investments which are approved by the Commission but where the property is already encumbered with liabilities

which are thought by the Commission to be excessive. Does the Commission, in determining whether to permit the addition of new capital, make, in all cases, a valuation and compare it with the existing liabilities, and if so, what happens in case there seems to be a large excess of capitalization? What would be considered an excess by the Commission? If it does make a complete valuation before issuing permits for increased capital, what steps are taken in that matter?

The question of the treatment of early losses, by the Wisconsin Commission, has been very marked in its point of difference from some other commissions, notably from the commission to which I have already referred—the Massachusetts Gas and Electric Light Commission. The tendency of the latter has been to be rather lenient in dealing with companies which have had early losses which they have not been able to make up by later gains—to be lenient with them in the matter of allowing a somewhat larger rate of return in a rate case than otherwise would be allowed; but they do not indorse the capitalization of those losses nor do they directly set them forth as a capitalized deficit in their rate decision, while the Wisconsin Commission, as I understand it, does attempt to set up a capitalized deficit. The question has arisen whether the Commission has ever come across cases where the profits have been large and not any losses or, if losses, so small that the profits greatly exceeded them. By losses we understand, of course, in this connection, failure to pay a reasonable dividend, and do not mean simply a failure to pay whatever the Commission may consider a reasonable dividend. When there has been such an accumulation of surplus above a reasonable return in the past history of the plant, I am not quite sure how the Wisconsin Commission treats that, whether it has pursued the same policy as to that through their history, or whether it may be a different policy from that which it pursued earlier, and I am sure the author will be very glad to give us a little light on that.

Some commissions in some states are rather hesitant about accepting some of the Wisconsin methods; not those, particularly, which have been mentioned thus far, but such matters as relate more particularly to the determination or control of municipal service,—whether a state commission should go further with the municipally-owned plant than to insist upon uniformity of accounts, perhaps good service; whether a city owning its own water works should or should not have the right to make money or lose money as it pleases, provided the citizens are correctly informed as to what is going on. In other words, we have two rising theories in this country,—the theory of state regulation and the theory of home rule,—which may come into great antagonism on that one point, for example. Also, the question of the extent to which a municipality should be allowed to go into municipal ownership. In Wisconsin, as I understand it, this cannot be undertaken now, in

connection with some plants, unless a jury of twelve men unanimously agrees that it is a matter of public convenience and necessity. At least, such a law has come before me lately as being on the statute books of Wisconsin, recently passed. Then, after that is done, the state commission fixes a price. I think it also, perhaps, approves of the experiment. I do not know that this jury trial relates to all cases of municipal ownership, but it does to some.

We are face to face with what I like to see, a glorious conflict of ideas. Through conflict, in the discussion of these subjects, we gain light, and we can carry it on with the very best feeling and with the idea that out of it all will come, in the long run, a just and wise solution for the public.

So, on the whole, I think we can welcome the Wisconsin Commission as conducting, in the most able manner, a great experiment in regulation, and we want all the light we can get with regard to its work.

W. J. Norton (N. E. L. A.): It is a great pleasure to hear from the principal rate representative of a Commission that has always looked its issue squarely in the face. As we read over the reports of some of the older commissions I think we are somewhat disappointed in the way in which they have dodged the issues, and it is refreshing to find a commission that is willing to stand on its feet and say that the going value or capitalization of early losses is a fair and proper thing, and that it is going to stand behind it.

Of course, we all have one criticism against the Wisconsin Commission. It has gone on record on the great engineering point of overhead charges on a 12% basis, for very good and sufficient reasons of its own; but it is so often quoted, and a good many of us feel that it is wrongly quoted, in other cases, and this 12% is a point that it is always necessary to throw a great deal of light upon from other sources. I sometimes wish that the Wisconsin Commission would make its reasons for its 12% overhead charge a little more clear for the benefit of some of those who use this decision as an argument in other cases.

My interest being mainly in rates, I was much interested in the author's statement that "in many cases the rates have been found to be unreasonably high as well as unjustly discriminatory." "Unreasonably high" is a little indefinite, and "unjustly discriminatory," particularly in such rate as electric light, is again indefinite because where electric rates are based on such a system as the demand system, and where for purely mechanical reasons we are unable to make accurate measurements of demand and must base such measurements upon assumptions, discrimination is apt to creep in. I wondered, as I read this paragraph, what the Wisconsin Commission has done in reconciling such rates as it found to be unreasonably high or unjustly discriminatory, with the provisions in the law such as Section 60, Part 3, which require

the company whose rates are so found to pay all the expenses of the investigation. From what I can learn, I think this part of the Wisconsin law has been rarely resorted to, but I find this section being repeated in the laws of other states, and I am wondering whether or not in other places it will always have the enlightened action that we know it has had in the state of Wisconsin. I would be very glad if the author would give us some information on this particular point.

Mr. Erickson: The first question asked this evening, I believe, was as to whether a law for the regulation of capital issues was enacted in Wisconsin. The first law was enacted the same year as the public utility law, but it was not an effective law. It left several things undecided and hence was not of very great importance. It did not give the Commission power to do very much. An effective law for the regulation of capital issues was not enacted until two years ago. Then a law was placed upon the statute books which gave the Commission the more complete control of capital issues, and the law seems to be working fairly well. I think on the whole it has reduced the rate of interest in the state by making public utility securities safer than they ever had been before; at any rate, statements by owners of public utilities have been made publicly to that effect.

Of course, when we find an over-capitalized utility, no commission can arbitrarily reduce its outstanding securities. In such cases all the commission can do is to see to it that the new additions and extensions to the utility are covered, or that the money raised by the additional issue is no greater than the investment. That is what the Wisconsin Commission is doing. Of course, as the values increase, the value of the utility grows nearer and nearer the outstanding issue, but that is very slow progress.

As to going value or capitalization of losses, I think perhaps that is a question which is not quite understood. I mean by that, the methods adopted by the Wisconsin Commission in dealing with such matters. In getting at the values the Commission endeavors to find out the original cost, not only of the physical property but also of the business of the plant. There is hardly a utility anywhere which does not require a great many expenditures before it comes to a fairly paying basis, in the way of building up the business. That is an element of investment or an expenditure which is as real as the investment in the physical property itself. It must be taken into account somewhere. If it is not, you will find it impossible to get money for public utilities at as low rates as you otherwise would, or as you will if you take such costs into account. In order to get at the original cost of the physical property and the business, the Commission endeavors to find out what the early losses were and it does so as far as they are available or accessible. But we also have another method. We endeavor to obtain the cost of reproduction of the property, that

is, of the physical property, as well as of the business at the time of the appraisal. The methods, of course, are well known by which that is effected.

Now, the two lines of inquiry, the two lines of development, constitute evidence of value only. They are developed as far as possible, together with all other facts which bear upon the value, and from all the facts available the Commission fixes the value of the plant and its business.

The value thus fixed seldom agrees with the original cost of the plant and the business, and often does not agree with the cost of reproduction of the plant and of the business. It is some figure which in view of all the facts appears to be reasonable under the circumstances. That is about the only method that anyone can pursue in the long run and arrive at fair or equitable results.

Something has also been said about state control of municipally-owned utilities. The Wisconsin Commission has control over the rates and service and other practices of municipally-owned plants. The City Councils still have the power to regulate the service, but they do not have power over the rates. Whether municipally-owned plants should be subject to state regulation is a question that is in controversy almost everywhere. It is a fact that municipally owned plants need regulation fully as much as and even more than privately-owned plants. Relatively more complaints are received by us affecting municipally-owned plants than privately-owned plants. In municipally-owned plants the accounts are poorly kept. Their rates are often discriminatory to a greater extent than is the case with privately-owned utilities. The rates are put in apparently in a haphazard way, without much regard to cost of the service and often largely for political reasons. That is also true of the service. That is, the service, while at times good, is frequently open to very serious objection. I am not making these statements because of the fact that the matter is discussed and is of a controversial character, but I am making them simply because they are the facts. There are very few municipally-owned utilities in the state that have not been hauled up before the Commission at least once, and in going through their records it is very difficult to get any line on their business. They usually keep their accounts mixed up with other business of the city. Everything goes into the general fund, and the money received from the utility is often used for any purpose that the city officials may choose to use it for. Incomplete or no records are made of the amount of water or current used by the city. There is often no reliable way of telling either the quantity or the service furnished or what has been received for it.

The Commission has been very lenient in matters affecting municipally-owned utilities. We have tried to nurse them along the best we could, and even when complaints are numerous we simply do the best we can to smooth things over.

Of course, in the case of a large public utility, such as the Milwaukee Water Works, the situation is much better. That

plant is in the hands of a competent superintendent who seems to know his business and who is really doing very good work. In the small cities, however, the plant is seldom in the hands of men trained in the business or who know much about the utility business. The administration of the plant is usually changed with changes in the administration of the city, and instead of there being an engineer or somebody who has experience in charge, they often put a good politician in charge.

As to overhead expenses, that is also a matter, I think, that is not quite understood. The Wisconsin Commission in the case of smaller utilities allows 12%. In the case of larger utilities, where there is a great deal of difficult city work to do, crossing rivers and work of that kind, which often involves considerable risk, we allow 15%. That, however, is the apparent figure, which is visible in determining the unit price upon which to compute the cost of the various elements. We nearly always allow 10% for contractors' profit. That is an element which entered into the unit prices or cost as a whole and is not given separately. However, if that were taken out of the unit prices where it appears, and added to the 12%, that figure would be considerably increased. It might not add 10% to that figure but it probably would add 7% to 9%, so that the overhead expense used by us is considerably higher than 12%.

We have explained that on several occasions, but it appears that our practice is not quite understood.

We find many rates that are what we call unreasonably high. We also find a great many rates that are unreasonably low. One practice is about as bad as the other. A rate which is too high is, of course, injurious. We all know that. A rate which is too low is about as bad. In the case of a privately-owned plant, it usually results in the destruction of the plant, in failure to keep it up, in poor service generally. Very few people in the long run will go down into their own pockets for means to keep up a plant. We find a good many plants in that situation.

That is especially true of the smaller telephone companies throughout the state. These companies were started, not by a man who understood the business, but by a group of local men who had no conception of the life of the property and the expenses involved. They started in by charging a very low rate, a rate which really did not cover operating expenses, to say nothing about depreciation. The result is that in a few years they find that the plant is worn out, that renewals are necessary, and that there are absolutely no funds with which to meet these renewals. Then the trouble begins. They come to the Commission, or apply to the Commission for authority to increase rates. Upon investigation we often find that the situation is also such that we have to permit an increase. If we did not permit an increase the people would, in the end, be without service; so it is a public necessity and it is in line with public policy to increase the rates. In a great many

instances we have had to increase the rate for telephone companies, for some electric companies, and gas utilities where such prices have prevailed or where they have been engaged in a somewhat serious rate war, as is sometimes the case.

When we find the rates too high, while we make a reduction and endeavor to determine the basis for a demand cost and a consumer cost, as well as for the output cost—and these costs can be determined—we seldom assess the utility the cost of it. When rates are too high they are not as a rule so high that it would be fair to assess the cost of the case against the utility, and in such cases very often the cost of the case does not amount to much. The section to which Mr. Norton referred has therefore not been applied to any great extent.

While the rates of a utility as a whole, that is, the total revenue, may be too high, it is quite often the case that part of the rates are too low. This is partly because of competition conditions, in which case one cannot do much of anything with them, and partly because of failure to understand the real nature of the utility business or of an electric lighting or power business. It is not always easy to tell whether the rates can be called really exorbitant or not. I mean by this specific rates. This is true even where the total revenue may be higher than it should be.

Kempster B. Miller, M. W. S. E.: I am glad to express my appreciation of this paper. I wish we might have more like it, not only for the benefit of engineers, to whose lot such investigations often fall, but for the guidance of those municipal and state commissions, particularly in the far West, who are at present struggling with these problems. It seems to me the author has presented this matter with such admirable clearness that it must be understood by all, and in such a sane way that the doctrines he has expounded cannot, in general, be severely criticised.

I would like to say a word about the overhead charges in the determination of plant costs, or, more properly, replacement costs, because I think that these overhead charges have usually been underestimated. Of course, the amount of the overhead charge necessarily depends on what has been included in making up the unit costs for actual construction work, and also on the liberality with which those unit costs have been estimated. As the unit costs for labor and material involved in actual construction work are usually figured, I believe that an overhead charge of 12% is too little, except, possibly, in very small plants. In some cases, where the plant is of such size as to make its construction extend over a long period of years, the item of interest during construction will alone almost equal that figure.

I notice that the author adds a contractor's profit to the unit costs, which does not show on the face of things and which, with the visible 12% that is allowed for overhead charges, brings the real figure up to something like 22% or 23%.

Mr. Erickson: Our figures run to somewhere in the neighborhood of 20%.

Mr. Miller: I think it is true that engineers must confess, with some shame, that in practice they have often underestimated rather than overestimated the cost of constructing things. Mere incidentals and unforeseen contingencies often become very large figures, particularly in hydroelectric properties. In the construction of a large utility, I believe that the author's 20% will often fall far short of the mark. I have made, with extreme care, a number of estimates on large utilities, and usually come out with a figure somewhat in excess of 25%. I know of one very large property where 50% would not cover it, and the property was well handled during construction at that. I feel that the general tendency in this direction, since the regulation of public utilities began seriously to occupy the minds of men in this country, has been to increase rather than to diminish the amount that should be allowed in plant values, over and above the actual labor and material costs involved in the construction work.

H. Almert, M. W. S. E.: It has not been my good fortune to be connected with any case before the Wisconsin Commission, and therefore any harsh words I may have to say do not apply to that commission.

I do not know where the term *used and useful* for the convenience of the public originated, but I have an idea it originated in the Wisconsin bill. I notice that many of the younger states in the West like the sound of that term, and they use it whenever they have an opportunity. I remember seeing, a short time ago, a bill drafted for one of the western states for a new commission, where it was stated that "property used and useful shall be the only property considered; that it shall be the duty of the commission to make an appraisal and determine the present value of such property; and that the utility shall be allowed to earn 6% thereon." I have wondered how much capital would flow in the direction of utilities in that state, if that threat were carried out.

In one of the older commissions this term *used and useful* has come up in a case which has been carefully considered. In that particular property the city was reasonably well served, as far as statistics could determine, but there was a clamor on the part of a number of real estate men and promoters of the city's welfare generally that the city desired the introduction of hydroelectric power, so the company, in compliance with that clamor, furnished hydroelectric power. After the expenditure of considerable time and money to obtain the power, it was immediately discovered that the equipment of the company, which had been adequately serving the public up to that time, was rendered useless because of the difference of phase and frequency of current which came in from the hydroelectric transmission; the equipment was useless even as a standby in case of emergency; there were no public utility com-

missions thought of at that time. So the company discarded their steam plant equipment, decreasing their plant account by the amount of the salvage, and still carrying the balance in their capital account, believing that if the time of reckoning came everything would be carefully considered and just allowances made. But when the question of rates came up before that commission, they did not look kindly upon their million dollars' worth of discarded property which had not been in service sufficiently long to have earned a proper amount to write it off when discarded, and the earning had not been sufficient after that time to have written it off. The commission has drafted a decision which will shortly be rendered, and if that element of value is left out of the basis on which a fair return is allowed, a great injustice will be done to that particular company.

In a case from which I have just returned, before one of the western commissions, an interesting point came up, in connection with the valuation of water rights. No decision in the case will be arrived at for some time, and in the meantime I hope the commissioners will consider the matter very carefully. One commissioner quoted from the constitution of the state, and from the decisions of the Supreme Court of that state, but did not give the commission's own view of it at all. Briefly, the law is this: Only such an amount as has actually been paid to the state or federal government for water rights will be recognized for capitalization in rate cases; any additional amounts paid by present owners to former owners when water rights were acquired will not be recognized. In most cases the original water rights were granted to timber interests—lumber interests—who went out and filed claims and paid \$1.50, or something like that, for water rights; then they developed the water power in a crude way for logging purposes. After they had cleared off all the useful timber, it was found in many sections that the ground was underlaid with minerals. The water rights were then sold and transferred to mine operators with a good round profit to the timber men. The miners then conducted their operations, and when the ore was exhausted they in turn sold the water rights with a profit to the present owners—the hydroelectric operators. Regardless of what the hydroelectric operators have paid for those water rights, as the case stands now they are not allowed to include anything in their capital account on which they ask the privilege of earning a fair return. It seems harsh and certainly unfair if such a ruling is to be upheld.

In the capitalization of the water rights in this particular case, I used a method by which I determined what the savings were from two standpoints—one the saving over what the cost would be for power generated by steam in that particular locality, and the other, the saving at which power could be purchased at wholesale from the hydroelectric companies in the neighborhood. (In the West many of the states are quite well covered with trans-

mission lines, so that there are many sources from which the supply can be obtained.) That cost (being approximately one-fourth to three-fourths the cost of generating by steam) showed what saving the company could effect by owning rather than purchasing its water power, and then capitalizing the saving as a basis for arriving at the value for its water rights. The figure used in the appraisal was much lower than the saving capitalized, thereby showing that the company was dividing the profits with the public. This particular case is one of admitting competition where a new company asked for permission to enter the field in which a company is now serving the public adequately. The engineers for the commission figured that on the same basis of capitalizing the saving, the incoming company's water rights were worth something like \$1,300,000 less than nothing, because power could be bought from existing companies cheaper than the company could develop its own power.

In the matter of capitalization, I think it is a little hard on many of the public utility operators to have commissions dictate to them just what the nature of their securities shall be. I think it will suffice if the commission determines what is a fair valuation of the property, what shall be a fair rate of return, and what is a fair discount for the money. In one case recently a commission intimated that if it arrived at a value of a property as \$1,000,000, the company should raise \$600,000 of 5% bonds at par, and should put in the balance, \$400,000, in stock, paying par value for the stock. The company should then be allowed to earn 5% on the bonds and, to be liberal, perhaps 8% on the stock. Fixed charges and a fair return they figured would then be 5% interest on \$600,000 in bonds, or \$30,000, and 8% interest on the \$400,000 of stock, or \$32,000. That would be a net rate on the whole capitalization of 6.2% as their judgment of a fair return on that property. In the first place, I will venture to say that no company could sell its bonds at par in that section, and it certainly could not sell its stock at par. So, if the commission's intimated ruling is carried out, a hardship will be done to that company, and it certainly will retard the flow of capital in that direction.

I think some of the recent decisions have been accepted by the utilities not because they are fair but for the reason that they are already in; their money is there and they cannot get it out. But I think the commissions should look further and see what the effect on capital is going to be in the future.

The hope for continued success of the privately-owned properties certainly lies entirely with the commissions, which are an improvement over municipal control with their local prejudices. At the same time, I think that the commissions are now regarded by the privately-owned properties much like a wild animal that has been tamed. He behaves as a domestic animal at this time, but one cannot tell when the call of the wild may cause him to turn around and bite them. I think there are two reasons for that. In the first

place, most of the public-utility laws, as now drafted, give no assurance that future legislation will not be enacted which may undo all the good that has been done up to this time. In the second place, another difficulty has arisen which reduces the efficiency of commission rule—the same reason why municipally-owned utilities seldom succeed, *i. e.*, the change in personnel. I recall that in one case Mr. Wm. B. Jackson, who is here tonight, and the speaker had to work long hours and with considerable haste in order to finish the work so that the present commissioners might render a decision before their term expired. Those commissioners have been working hard for some six years to acquire the information which Mr. Jackson, the speaker and others have acquired in a lifetime, and now that they have become useful as commissioners, their terms have expired and they will be replaced by new and inexperienced men who in turn will require several years of study before they can render intelligent decisions. For that reason I think considerable additional legislation and safeguards should be thrown around commissions in order that they may better serve the public and the utilities.

Wm. B. Jackson, M. W. S. E.: I wish to join with one of the earlier speakers in congratulating the state of Wisconsin on the stable tenure of office of its commissioners, and the fact that the state is able to hold competent public utility commissioners in its employ.

I am glad to have this opportunity to echo what Mr. Arnold has so well said regarding the Wisconsin Commission and Mr. Erickson, because I think it expresses the situation admirably. It seems to me that the Wisconsin Commission has endeavored to take the best that could be found of the procedure of courts and earlier commissions, and from that point forward we must recognize that it has been breaking virgin ground.

In connection with the author's statement that in general it is less costly to supply inadequate service than to supply good service, I would ask whether the Commission is ready to give any figures to show the extent to which the cost of service may be effected by the rendering of poor service as compared with good service?

In regard to the question of rates based upon cost, the fact is brought out that there must be a modification of what may be called the pure cost basis. There are many cases where the benefits of central station electric service should be had but where such service can be provided only by giving very low rates, owing to conditions of competition or other factors which one frequently finds in practice. I would like to know what the author considers the line between equitable and inequitable rates (and by this I mean schedules of rates, because we must understand that any rate which is promulgated in Wisconsin must be a rate that anyone may enjoy

under conditions of like service); whether it is appropriate, under conditions as suggested, to promulgate a rate, the introduction of which will make possible an improvement (even though it may be ever so little, in cost of service to the remaining customers, although the customers under the rate may not nearly pay the average profit.

There is still another question that I wish to ask; that is, whether in the state of Wisconsin the Commission has ever found it necessary to give a certificate of public necessity for a competing plant, and if so, what the conditions were which led to the giving of such a certificate.

B. Hoffman: The author spoke of the waste of unnecessary duplication, and in the technical press there have been references to enforced prevention of duplication, namely, the Benecia cut off case, the Peoria case, and the requisition on the Michigan Commission that a certain trolley road should be allowed to use the Michigan Central bridge between St. Joseph and Benton Harbor. Has any such case been met with in the Wisconsin rulings?

Mr. Erickson: There is unquestionably great waste when two interests cover the same territory. We have been troubled with matters arising out of that condition, especially in Milwaukee and a few other cities in the state. The franchises were granted before the public utility law came into effect. The existing utilities have tried to get territory away from each other. Of course, that means two sets of distribution systems and also a doubling up of the investment in many other respects. We have in all cases endeavored to put a stop to such practices. We have investigated the matter, made proper rates for all utilities and confined each one to the territory it had had. They are permitted to develop the territory they have, but we do not often allow them to go outside of it, because there is waste involved and additional costs incurred.

In most of the cases we find that the best thing for all concerned is to put some sort of a check on practices of that kind, and we are doing this.

R. F. Schuchardt, M. W. S. E.: I think Mr. Erickson has given us an inkling of the reason for the success which has attended the work of the Wisconsin Commission. In discussing conditions frequently prevailing under municipal ownership he said, "I am not making these statements because of the fact that the matter is discussed and is of a controversial character, but I am making them simply because they are the facts." Apparently the Commission has tackled every problem with the intention of learning the facts and basing conclusions on their findings of facts instead of on the desires of influential vote-controllers. But, perhaps, more important is the fact that the Commission consists of men like Mr. Erickson who is apparently so truly the right man in the right place. The

breadth of view and the sound judgment exercised by the Commission, and so clearly set before us this evening in this valuable and interesting talk, inspire confidence and explain why so many of the states, which are at present engaged in developing public utility laws, are modeling these laws after the Wisconsin regulations.

Mr. Erickson: I will say a little more about overhead expenses and about the term *used and useful*.

Overhead expense, as used by us, includes (I will repeat now some of the things I said before) 12 to 15%, depending upon conditions. It also, in the unit costs, includes a fair amount for contractors' profit, bringing the total probably well above 20%. In addition to that, we often have to take into account discounts on loans, if a bond which bears the ordinary rate of interest cannot be sold at par. If the extension to the utility or the utility itself is needed (perhaps more than the money), then such discounts should be taken into account. It often happens that a 6% bond sells at no higher a price than 92. It is often best to take this discount into account in the value of the plant and to secure the money and the improvement. After all, the final standard in all matters of this kind is, what can you get the money for? If you cannot get the money for 5 or 6%, you must raise the value or raise the rate of return. A large proportion of the work of the Commission in almost every case of this kind consists of determining from all possible sources what, under the circumstances, capital can be had for. If you cannot get it at less than 8%, you have to permit 8% on the value. If you can get it for 7%, then this rate may control. The rate at which money can be had, is a question of fact. It is a matter that can be approximately determined in each case and it must be the thing to be guided by, because if you do not pay that return you will not get the capital. If you do not get the capital you cannot get the utility or the extensions.

Another thing about the term *used and useful* is this: Under the definition placed upon that term by the courts, it seems to include all amounts judiciously expended in securing the plant, its rights, and its business. That means that the term includes tangible as well as necessary intangible value. There ought to be some fairly definite relation between bonds and stocks. If the bonds cover the entire property, then the management, the operation of the property, is entirely in the hands of parties who have no real interest in it. That is not always safe, and we have frequently found that it works out anything but well. Hence we require that there shall be a fair relation between the two. The Commission, however, is sometimes perplexed or troubled about fixing that relation, for again it is up against a question of fact. If you cannot sell stock you have to issue bonds, if the money is needed or if the

extensions are needed. Consequently, we have to permit bonds up to very nearly, though not entirely, the full value of the extensions, perhaps to as high as 90 or 95%.

As to whether inadequate service can be furnished more cheaply than adequate service, I might perhaps say this: It is unquestionably a fact that gas, for instance, having a heating value of only, say, 500 B. t. u., can be furnished much cheaper than gas having a heating value of 600 B. t. u. Here is one instance where a low grade service is cheaper than high grade service. The same situation may apply in the case of street railway service. By overcrowding and delays, the service can undoubtedly be performed through less car mileage than when enough cars are run to prevent overcrowding and delays. The same thing also applies as to voltage in an electric lighting plant. Better equipment and greater care are required in keeping the voltage up to a fairly even level than to let it run as it wants to; although after a fair standard of voltage has once been settled upon, I think perhaps it can be maintained nearly as cheaply as the lower standard of voltage.

As to the additional cost basis of rate making, that is a very important matter. Electric current, for instance, comes in competition with steam, with producer gas, and sometimes other power. Many are of the impression that under a public-utility law each class of service has to yield relatively the same rate of profit to the utilities. Of course, that does not mean the same rate, because some service costs more than other service, but the profit, in the minds of many, has to be the same. Now, as the law is interpreted by us, that is not the case. We work out a rate schedule which is based upon a proper apportionment of the total cost and such a classification of the service as we think ought to be made. That is, we put in one class residences; in another class, the commercial service, business service, store service, and so on. Then there are, perhaps, four or five classes of power service, depending upon conditions. Frequently a large power user simply will not take current at a rate which will yield anywhere near 6% or 7% or 8% profit on the investment. With a case of that kind, about the only thing one can do is to find out the additional cost to the plant of serving that customer and add a little to that cost so that it will contribute something to the profits, and then place that customer in a class by itself. It may be only one customer, but when this can be done without unjust discrimination, we create a class for that customer and place him upon a different basis from the other customers. If anyone comes in under the same condition he can get the same rate, but it may apply to only one customer. If that customer can thus be taken at a rate that covers the additional cost of serving him, plus perhaps 1% or 2% on the investment used by

him, it goes into the total fund and reduces by that much the amount the rest of the customers have to pay. Hence, it is good policy to take that customer. We always see that he is taken whenever there is any way of doing it, and in most cases there is. A street railway was taken on by the local electric lighting plant, on that basis, at a very low rate of profit.

This last week we worked out a rate schedule under which four power users in the city were taken on the additional business basis. Each man, however, had to be placed in a class by himself in order to furnish the service and we did create a class for each customer. But these four users were large users—manufacturing establishments operating from eight to ten hours a day—and the amount they contribute to the total amount is, of course, a very valuable addition, not only to the plant and its income but also to the rest of the consumers.

The Commission has not at any time granted a certificate of convenience and necessity to a competing utility. We have been able to get the existing plant and the people together, and by treating the matter rather considerately, capital could be obtained for the necessary extensions of the service—such improvements as those to which the public were entitled—and the lack of which caused the trouble.

IN MEMORIAM*

HORACE EBENEZER HORTON, PAST-PRESIDENT, W. S. E.

Died July 29th, 1912.

The value of a man's life is measured by his contributions to the welfare of his fellow creatures. The seeds of his influence fertilize and bear fruit in the lives of those who know him personally, and in accord with the laws of Nature, multiply and are distributed in directions and in volume beyond our knowledge, their ultimate value being known only to the Creator. The fruits of a good life are not exhausted in the short space of years during which the liver meets his fellows face to face, and if he has done well in that period it is fitting that a memoir of his life should be preserved for the encouragement of those who come after him, and this is especially so when the subject of the memorial has staked out a path to be trodden by those who follow in the line of his professional work. Some account of the life of an engineer whose practice covered the period of progress of the profession from a primitive stage to its present condition, during which he contributed more than an average share to its advancement, must be instructive and inspiring to other engineers whose work lies before them.

The subject of this memoir, Horace Ebenezer Horton, attained high rank as a bridge engineer, doing pioneer work under difficult conditions in his early manhood, and was conspicuous as a leader in his profession throughout a long, honorable and useful career. For an appreciation of his life it is well to consider the conditions which surrounded him from infancy, with his opportunities for education, and the environment under which his problems were solved.

Mr. Horton was born in the village of Norway, Herkimer County, New York, December 20th, 1843, and died at the age of sixty-nine, at his home in Chicago, July 29th, 1912. He was of Puritan descent, and his paternal ancestry for several generations resided in the eastern portion of Long Island. He inherited qualities of probity and industry for which he was noted in his professional life. His father was by occupation a carpenter and builder, and was said to be of an enterprising and resourceful nature and capable of doing unusual mechanical work. Mr. Horton's boyhood was spent on a farm occupied by his parents, just out of the village of Norway. It is on the farm that a young boy has exceptional opportunities for acquiring the sense of responsibility essential to true manhood. The chores he must do, the at-

*Memoir prepared by the following Committee: Onward Bates, W. L. Cowles and C. R. Dart, Members, W. S. E.

tention to farm animals, which must without fail, be fed, watered and cared for, are an education in the line of duty not usually enjoyed by boys reared in a city home. We may assume that this boy on the farm learned at an early age to think and act for himself, to acquire a confidence in his own powers and a conscientious regard for duty which fitly prepared him for the pioneer life to which he was introduced at the age of thirteen, when he moved with his parents from Norway, New York, to Rochester, a village in the new state of Minnesota. This was in 1856, a time when the country was in a political ferment presaging national strife, and culminating in the Civil War. The whole nation was stirred to its depths, and the boys as well as men discussed and reflected on great questions affecting our whole citizenship. The war came on and the ranks of fighters were filled with young men of little more than Horton's age. When the war ended, its survivors faced the problems of reconstruction and there were unusual opportunities for victories of peace. It was a period calling for qualities of self reliance and of action. Such conditions were inspiring to a young man whose boyish thoughts had been directed to serious and venturesome affairs and he would be fired with an ambition to do notable things. The circumstances surrounding Mr. Horton's boyhood were educational and were reflected in his mature life.

Mr. Horton did not enjoy the opportunities for education in the schools, now offered to all who will use them. Half a century ago, schools were primitive as well as few in number. Engineering schools were practically unknown, and engineering could scarcely be called a profession. He attended school in Rochester, and spent two years at Fairfield Seminary in Herkimer County, New York, and was less than twenty years old when his school days ended. Like all engineers, whether university men or not, he had to educate himself, and it may well be questioned if he was not better trained with his self education supplemented by the limited school instruction, than if given the equivalent of a full course at a modern university. Education proceeds largely from within, depending on the man himself, and with young Horton as his own teacher, a good education was a foregone conclusion.

When only twenty-three years of age, without any previous experience, or any aid from outside sources except his own reading, he designed, contracted for and built a timber arch bridge in the village of Oronoco, Minnesota. This bridge was 60 ft. high above the water and had a clear span of 186 ft. It was an efficient structure and would at this date be counted a creditable one. When we reflect that it was built forty-seven years ago it will properly be considered a remarkable structure. That one so young in years, without experience or precedents, could in a new country, plan, obtain the confidence of those who paid for

the bridge and at his own risk, build it, evidences the character of the young man, and is an indication of what was to be expected of him in his maturity. The successful completion of the Oronoco bridge led him into the occupation of bridge building. At that date the contractor who had the courage to build a bridge was his own engineer, or putting it differently, the engineer who designed a bridge had to justify his design by being his own contractor. It was the custom for the engineer to make proposals for building bridges and he risked his money with his reputation. Let it be remembered that forty odd years ago there was scarcely any literature on the subject of bridge building, there were few examples in this country of notable bridges, that instead of corporations with great bridge shops and improved tools, there were no special tools and conveniences for construction, and bridge builders were engineers or practical men with natural talents for such work and a spirit of enterprise leading them to take risks for the pleasure of conquering obstacles. It was required of the successful bridge builder that he should combine with the ability to design, an equal ability to provide the means for the executing of his design.

About the time Mr. Horton became a bridge builder the country was being rapidly settled with a growing population and there was great demand for bridges over its numerous streams. These bridges had generally to be built at the least possible cost. It was frequently the case that the construction of a bridge was dependent on its cost being within the sum of money which could be raised for the purpose. The demand was for inexpensive bridges to provide the means of communication in a sparsely settled country where wealth had not yet accumulated and the construction of such bridges was a boon to communities, the value of which never has, nor can be estimated. Mr. Horton was one of the early engineers who met this demand for economical bridges and who served their country well, providing safe bridges at low cost, setting precedents of construction and types of structures, and establishing this branch of the profession.

Mr. Horton possessed unusual ability as a designer. He was amongst the foremost in the production of new features of design, seeming to grasp the requirements of each particular case and equally ready to plan the finished structure adapted to each case, and to devise the plant and methods of fabricating and erecting the material. In a new country where timber was cheap and available his first bridges were of that material. Then he was one of the first to build what are called combination bridges, in which the compression members are of timber and the tension members of metal. He built a great number of such structures and with headquarters at his home in Rochester, Minnesota, his business as a builder of wooden and combination bridges extended throughout the states of Minnesota, Wisconsin, Iowa and Illinois.

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As the art of bridge building advanced, Mr. Horton maintained his place with the most advanced of bridge constructors. With the growing scarcity and increased prices for timber, the reduction of cost of iron and steel and new facilities for its manufacture and the greater ability of communities to pay for permanent structures, he met the new conditions as a designer and builder of metal bridges. It is claimed that he was one of the first to use the camelback type of fixed truss both in metal and in combination bridges, and was also a pioneer in building bridges of the cantilever type. A number of notable bridges were designed and built by him as engineer and contractor, and as a contractor for a much larger number, he prepared the detail plans based on the general ones furnished to him. Skill in design, in workmanship and erection were features of all his work. In the list of bridges built by him are five across the Mississippi River, at Onoka, Fort Snelling, Winona, Dubuque and Lyons, all notable structures and particularly described in a paper by F. B. Maltby on "The Mississippi River Bridges," published in the *Journal of the Western Society of Engineers*, in 1903.

In addition to his work as a bridge builder Mr. Horton was an architect of considerable ability. While still a young man he designed for the State of Minnesota the buildings comprising a hospital for the insane at Rochester, and he built there and in some neighboring cities a number of school houses and other public buildings. He was at all times referred to by his friends for advice and sometimes for plans of dwelling houses.

As a consequence of being a most resourceful man, independent and self confident, Mr. Horton was better adapted to working as his own master than in the service of another and perhaps may be said to have been stronger as an individual than in team work. Up to the year 1889 he lived at his home in Rochester, from which place he conducted his business as a contractor. With the change from timber to metal construction it seemed necessary that to obtain material for his contract work, he should establish a shop for its manufacture, and selecting Chicago for a location he moved his family residence to that place, where with some others he organized the Chicago Bridge & Iron Company. In the shops so established he continued his business as a bridge builder, manufacturing his own metal work. While the primary object of this Company was bridge building, he was a manufacturer as well as a builder and with the plant at his command was able to take up new lines of construction. In 1894 he perfected a design for elevated steel water tanks which possessed fundamental elements of superiority over the practice of that date, and the manufacture of such tanks developed into a large and profitable business. One of these tanks built by him at Louisville, Kentucky, is said to be the largest of its kind, having a capacity of 1,200,000 gallons, the total height of the tank and its supporting tower being 200 feet.

In 1897, the plant of the Chicago Bridge & Iron Company was destroyed by fire. This gave Mr. Horton an opportunity for re-establishing himself as an individual which he used by buying the stock of his associates, rebuilding the shops and conducting the business under the title of Horace E. Horton, Proprietor, Chicago Bridge & Iron Works. In rebuilding this plant, Mr. Horton's individuality and his mechanical ability were shown in the planning of the buildings and plant. Nearly all the machinery was made to conform to his ideas, many unique features being introduced, and its efficiency was fully demonstrated by the results accomplished.

An important element of Mr. Horton's character was his ability to analyze any problem set before him, and with unusual clearness of perception to quickly discern the salient points and reach a conclusion. This was exhibited in his practice as a constructor, and equally so in the discussion of engineering subjects, and whatever Horton said in public or in private was worth listening to. His originality of mind enabled him to set forth a proposition in a manner striking and effective and with convincing logic. For this reason his presence was sought in meetings of engineers and his fund of natural humor, sometimes quaintly expressed, made an agreeable frame to the strong sense of his statements. He took his place with his fellow engineers and had a part in their combined activities. He became a member of the Western Society of Engineers in 1881, and in 1895 was honored by election to the office of President of the Society. He joined the American Society of Civil Engineers in 1882 and served it as a Director in 1907 to 1909. His contributions to engineering literature, while not extensive, were valuable. On various occasions he read or discussed papers before the local and national engineering societies and his treatment of subjects was made effective by his insistence on attention being given to successful practice as furnishing a valuable guide, and on the necessity of using sound judgment and common sense in interpreting facts and in applying theory.

Mr. Horton's interest was not confined to engineering subjects. He was a large man in mind as well as in body, both well proportioned, and with a warm heart and genial good nature was a welcome companion to a host of friends. He liked companionship and mingled with his fellows in business and in social gatherings as well as in professional ones. Among other relations he valued highly his membership in the Sons of the American Revolution, at whose meetings he was an almost constant attendant, voicing his strong patriotism and good-fellowship.

Mr. Horton was married in 1871, to Miss Emma Babcock, of Waupun, Wisconsin. He is survived by his wife and five children: George T. Horton, of Chicago; Mrs. R. H. Murray, of Greenville, Pa.; Mrs. Karl K. Koessler, of Chicago; Horace B. Horton, of Chicago, and Hiram T. Horton, of Greenville, Pa.

FRANCIS HENRY BAINBRIDGE, M. W. S. E.

Died December 3, 1912.

Francis Henry Bainbridge was born in 1863. As a boy he went to work for the Troy Steel and Iron Company of Troy, New York, and later was clerk with the Fuller Warren Stove Works of Troy.

Before attending college he was draughtsman in the granite quarry at Barre, Vermont. Graduating from the Rensselaer Polytechnic Institute with high honors, he soon thereafter became inspector on the Northern Pacific Railway. In the desire to attain a varied experience, he held many positions, some of them of notable importance.

After leaving the Northern Pacific Railway Co., he was successively draughtsman for Buck & McNulty of New York; draughtsman and later principal assistant engineer for the Edge Moor Iron Works of Wilmington, Delaware; resident engineer for the Pencoyd Iron Works in Chicago; superintendent for Christy & Lowe on the Chicago Drainage Canal and other work; engineer of bridges of the Chicago & North Western Railway, and the Illinois Central Railroad; principal assistant engineer and later assistant chief engineer of the Chicago & North Western Railway.

Not only as a designing and directing engineer was Mr. Bainbridge's work noteworthy, but also as a resident engineer in the field. He was in direct local charge of the bridge over the Missouri River at Pierre, South Dakota, and over the Mississippi River at Clinton, Iowa, for the Chicago and North Western Railway. In both of these, he also had charge of the construction work of the line adjacent to the bridges.

His last work was as resident engineer for the Milwaukee, Sparta and North Western Railway, a subsidiary line of the Chicago and North Western Railway. His health gave out while on this work, making it necessary for him to resign. For a time he was at the North Shore Sanitarium, Winnetka. After leaving the sanitarium, with his health apparently improved, he was again about to enter active engineering work when he suffered a relapse from which he died on December 3, 1912.

Mr. Bainbridge was the inventor of a steel dam patented in 1894. Several of these have been put in by the Wisconsin Bridge & Iron Co., notably those at Ash Fork, Arizona, for the A. T. & S. F. Ry. System; at Redridge, Michigan, for the Atlantic and Baltic Mining Co.; and near Helena, Montana, by the Helena Power Transmission Co.

Memoir prepared by the following Committee: W. H. Finley, T. W. Snow, and I. F. Stern, Members, W. S. E.

Mr. Bainbridge was of a generous open-hearted disposition, and of magnificent physical build in keeping with his intellectual attainments. He was a deep student in many lines, not only of engineering and geology but of music and of English literature. He was a forceful writer and contributed many articles to the technical press. He contributed two papers to the Western Society of Engineers. The first one, "Rebuilding of the Kinnickinnic River Swing Bridge on the Chicago & North Western Railway, at Milwaukee, Wisconsin," published in the Journal for April, 1900, Vol. V, p. 127. The second one, "Structural Steel Dams," published in the Journal for October, 1905, Vol. X, p. 615. He became a Member of the Western Society of Engineers November 27, 1893.

Mr. Bainbridge had never married, and is survived by his mother, a sister, and two brothers.

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Extra Meeting, April 28, 1913.

An extra meeting of the Society (No. 822) was held Monday evening, April 28, 1913,—a meeting of the Electrical Section W. S. E., held jointly with the Chicago Section A. I. E. E.

The meeting was called to order by the Chairman, Mr. R. H. Rice, at 8:30 p. m. with about 75 members and guests in attendance. The Chairman announced that the nomination and election of members of the Executive Committee, Chicago Section A. I. E. E., was in order. Mr. Wm. B. Jackson offered the following names as nominees.

D. W. Roper for Chairman, to serve one year.

E. W. Allen for Secretary, to serve one year.

R. H. Rice for Member of the Committee, to serve three years.

As no other nominations were made, on motion, the Secretary of the Section was instructed to cast the ballot for those nominated. This was done as ordered. Mr. Rice stated that the hold-over members of the Executive Committee, Chicago Section A. I. E. E., were Messrs. J. G. Wray and Wm. B. Jackson.

Mr. Rice then stated that there was present, Mr. Ralph D. Mershon, President A. I. E. E., also Dr. W. F. M. Goss, President A. S. M. E., as well as Mr. Albert Reichmann, President W. S. E., and Mr. P. M. Chamberlain, Chairman of the Chicago Section A. S. M. E. Dr. Goss, M. W. S. E., was asked to preside, which he did admirably. President Mershon was introduced to the meeting. He spoke of the advantages and benefit of these joint meetings, and that great good to the profession at large is obtained by the members coming together and in uniting their efforts, co-ordinating the efforts of the several societies to secure results.

Mr. Mershon spoke of the necessity of reorganizing the U. S. Patent Office, and correcting the present practice. If the several societies would unite and bring their influence to bear, much good could be accomplished in this work. Discussion followed from Dr. Goss, President Reichmann, P. M. Chamberlain, A. Scheible, S. Montgomery, P. Junkersfield, W. C. Bauer, D. W. Roper, R. F. Schuchardt, A. Bement, and Wm. B. Jackson, with a closure from Mr. Mershon.

Prof. P. B. Woodworth offered a motion, that it is the sense of this meeting that a special commission should be created to reorganize the patent office practice. Motion carried.

Mr. D. W. Roper offered a vote of thanks to Mr. Mershon for his trip to Chicago to give such a valuable address. Carried.

Mr. Rice announced that the next joint meeting would be held in four weeks, May 26, when Mr. H. E. Chubbuck, Vice President of the Illinois Traction System, would address the meeting.

Meeting adjourned at 10:10 p. m.

Regular Meeting, May 5, 1913.

A Regular Meeting of the Society (No. 823) was held Monday evening, May 5, 1913. As there was not a member of the Board of Direction present, the Secretary called the meeting to order at 8:15 p. m., and asked them to select one of their number as Chairman. Mr. F. W. Dencer, M. W. S. E., was nominated and elected to act as chairman of the meeting.

The Secretary of the Society reported from the Board of Direction at their meeting of April 3, the names of the following that had applied for admission into the Society were presented.

Application No.

26. Frederick William Smith, Milwaukee, Wis.
27. Malcolm Campbell, Montreal, Canada.
28. Carl A. Gaensslen, Chicago.
29. Thomas V. Salt, Chicago.
30. Arthur C. Lindstrom, Chicago.
31. Heber G. Gearhart, Chicago.
32. George D. Lewis, Ottumwa, Iowa.
33. A. J. Albert Anderson, Chicago.
34. Henry Olmstead, Jr., Chicago.
35. Guy F. Stinchfield, Valparaiso, Ind.
36. Frederick William Green, Stamps, Ark.
37. Arthur Thomas Maltby, Chicago.
38. Eugene F. Hunter, Rochester, Ind.
39. Peter M. Leichenko, Chicago.
40. Will Gerald Shurgar, Meridian, Miss.
41. Alexander S. Murison, Chicago.
42. Charles H. Poole, Chicago.

Also that at that meeting the following were elected into the Society :

Application No.

Grade.

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| 10. Carl W. Chase, Gary, Ind..... | Member |
| 11. Samuel E. Stout, Gary, Ind..... | Associate Member |
| 12. James W. Pearl, Chicago..... | Member |
| 13. Charles L. Weiss, Chicago..... | Junior Member |
| 14. Ray C. Yeoman, Valparaiso, Ind..... | Associate Member |
| 17. Victor H. Bell, Valparaiso, Ind..... | Student Member |
| 18. Paul M. LaBach, Chicago..... | Member |
| 19. Mahlon J. Hammer, Chicago..... | Member |
| 21. Edwin C. Hall, Chicago..... | Member |
| 22. Max L. Lowenberg, Chicago..... | Junior Member |
| 25. Paul Hansen, Urbana, Ill..... | Member |

And also that the Membership Committee had given further consideration to the application of Robt. E. Calwell of Beloit, Wisconsin, and recommended that the Board of Direction reconsider its action of November 29, 1912, and elect Mr. Caldwell a Member, which was done.

The Secretary also reported from the Board of Direction that at their last meeting, May 2, 1913, the following had applied for admission into the Society :

Application No.

43. Oliver Louis Bear, Chicago.
44. Louis G. Arnold, Chippewa Falls, Wis.
45. Benjamin H. Crosland, Rochester, N. Y.
46. Theodore R. Minert, St. Paul, Minn., Transfer.
47. Louis Carl Mory, Lombard, Ill.
48. Edmund F. Barkow, Milwaukee, Wis.

Also that the following had been elected into the Society :

Application No.

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| 15. John L. Parsons, Humboldt, Iowa..... | Associate Member |
| 20. Thomas D. Mylrea, Winnipeg, Manitoba, transferred from Junior to..... | Associate Member |
| 23. Willard E. Lofgren, Chicago..... | Associate Member |
| 24. R. T. Logeman, Chicago..... | Member |
| 26. Frederick W. Smith, Milwaukee, Wis..... | Member |
| 28. Carl A. Gaensslen, Chicago..... | Associate Member |
| 29. Thomas V. Salt, Chicago..... | Member |
| 30. Arthur C. Lindstrom, Chicago..... | Junior Member |
| 31. Heber G. Gearhart, Chicago..... | Associate Member |

32. George D. Lewis, Ottumwa, Iowa.....Junior Member
33. A. J. A. Anderson, Chicago.....Student Member
35. Guy F. Stinchfield, Valparaiso, Ind.....Member
36. Frederick W. Green, Stamps, Ark.....Member
37. Arthur T. Maltby, Chicago.....Member
38. Eugene F. Hunter, Rochester, Ind., transferred
from Junior to Associate Member
39. Peter M. Leichenko, Chicago.....Junior Member
41. Alexander S. Murison, Chicago.....Student Member
42. Charles H. Poole, Chicago.....Associate Member

There being no other business to bring before the Society, the Chairman, Mr. Dencer, introduced Mr. W. H. Radcliffe, M. W. S. E., Assistant Engineer, American Bridge Co., who read his paper on the Erection of the Municipal Bridge at St. Louis. After reading the paper, a number of lantern slide views were shown in illustration, and a general discussion followed, asking and answering questions about the details of the work.

The meeting adjourned at 9:50 p. m.

Extra Meeting, May 12, 1913.

An extra meeting of the Society (No. 824), the Bridge and Structural Section, was held Monday evening, May 12, 1913. The meeting was called to order at 8:20 p. m., with Mr. I. F. Stern presiding and with about 35 members and guests in attendance. The Chairman introduced Mr. Geo. S. Rice, M. W. S. E., who read his paper on "A Suggested Method of Preventing Rock Slides." After the paper was read, some lantern slide views were shown, and discussion followed from Messrs. H. J. Slifer, Ernest McCullough, John F. Hayford, U. S. Grant, Andrews Allen, and E. N. Layfield, with a closure from Mr. Rice. Mr. Reichmann offered a motion, which was seconded and carried, of a vote of thanks to Mr. Rice for his paper.

Meeting adjourned at 10:30 p. m.

Extra Meeting, May 19, 1913.

An extra meeting of the Society (No. 825)—the Hydraulic, Sanitary, and Municipal Section—was held Monday evening, May 19, 1913.

The meeting was called to order at 8:20 p. m. by Mr. Langdon Pearse, Chairman, presiding, with about 90 members and guests present, including a number of ladies. There was no business, so the Chairman presented Mr. John Ericson, City Engineer, who read his paper, "The Chicago Water Works." This was illustrated with many fine stereopticon views. Discussion followed from Chairman Pearse, Col. Henry Allen, and Messrs. Samuel Artingstall, H. S. Baker and L. K. Sherman.

A vote of thanks was tendered Mr. Ericson for his paper.

Meeting adjourned at 10:20 p. m.

Extra Meeting, May 26, 1913.

An extra meeting of the Society (No. 826), a joint meeting of the Electrical Section, W. S. E., and the Chicago Section, A. I. E. E., was held Monday evening, May 26, 1913. The meeting was called to order at 8:25 p. m. by Mr. R. H. Rice, Chairman, and with about 45 members and guests in attendance.

A paper on "Cost Systems in Electrical Contracting," by Mr. Leo Dolkart was read by the Secretary, in the absence of the author. Discussion followed from Messrs. R. H. Rice, S. Montgomery, E. H. Freeman, C. A. Keller, H. S. Pardee, and C. D. Wosselhoef.

The meeting adjourned about 9:45 p. m.

J. H. WARDER, Secretary.

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THIS SOCIETY.

THE OFFICIAL GOOD ROADS YEAR BOOK OF THE UNITED STATES, 1913. American Highway Association, Colorado Building, Washington, D. C. Cloth, 6 by 9 in., pp. 548.

This is an enlarged and second edition of a valuable book, noted in these pages last year (XVII-811), and is a welcome addition to our library.

Following the Preface is a section on History of Road Building, with reference to the Romans and the French as road builders. Following, is an account of the Road System of Foreign Countries, and a chapter on National Aid to Road Improvements, in which is listed various congressional bills introduced into the Sixty-second Congress for the aid of public highways.

"Road Legislation in the United States" follows, first national and next according to the several states, showing what has been done, here and there, on behalf of good roads. This record of the work of the several states covers 140 pages. The next chapter discusses Types of Roads, as, Earth, Sand-Clay, Gravel, Macadam (Waterbound and Bituminous), Brick and Concrete as the surface construction. Highway Bridges and Culverts follow, ten pages of text and engravings, and then comes Road Maintenance and Repair, with an illustration of a road drag for use particularly on dirt roads. The "Massachusetts Specification for State Highways" is valuable as showing what is the practice in that Commonwealth.

The modern and progressive movement in favor of good roads is set forth in State Progress Reports, some 32 pages, and it is encouraging to learn what is being done.

Highway officials, of the United States Department of Agriculture, and of the several states, is a valuable chapter for reference, and covers about 14 pages of text. The public interest in the subject of Good Roads is shown in about 20 pages of Highway Engineering Education. This is a list of 56 schools, colleges, and universities in the several states which have courses of instruction in highway engineering.

Of considerable value is the list of Treatises on Road, Bridge and Culvert Construction and allied subjects, which gives some 165 titles or subjects. This is followed by a similar list of Bulletins, Circulars and Documents published by the Federal Government and by several states.

The subject of Convict Labor receives some attention, 16 pages, stating the practice, regulations and results in different states in the use of such labor. Another interesting chapter gives the Mileage of Roads, by states, which has a decided statistical value. There are about 34 pages of lists of Bonds issued by state and county authorities to help road construction. Also about 26 pages of lists of associations other than the American Highway Association, but interested in this subject of good roads. There is also a considerable list of contractors for Road, Bridge and Street Work, and of Manufacturers of Road Machinery and Equipment.

Altogether this book is of considerable value and interest.

SPECIFICATIONS FOR STREET ROADWAY PAVEMENTS, with instructions to inspectors on street paving work. S. Whinery. Mem. Am. Soc. C. E. McGraw-Hill Book Co., New York, 1913. Second Edition, Revised and Enlarged, 6x9 in. Cloth, 116 pages. Price, \$1.00.

This book, originally a pamphlet, appeared some half a dozen years ago. In the interval since then, great progress has been made in the Art of Road Making, in which work the author has had much experience.

Part I, relates generally to specifications, the theory of them, the neces-

sity for and limitation in them, the necessity of fairness and justice to the contractor, the relation between them and the contract, and their preparation. Then comes specifications more in detail, and by numbered sections, for more ready reference, as well as covering all the various steps in construction. This includes foundation, different forms and kinds of pavements, as sheet asphalt, asphalt block, granite block, brick, wood block, bituminous concrete, hydraulic concrete, concrete curb and gutter, and concrete sidewalks. These various subjects are treated in detail and at some length, measuring up to 88 pages.

Part II, is devoted to Instruction to Inspectors. This is also divided into sections for more ready reference, and is very clear and specific in the instructions as to how the work is to be done, what to avoid, what may be done, special points to be noted, etc.

To the young engineer, the statements in the introductory should be of great value, as showing clearly the basic principles of specifications, and their relation to the contract. The author prefers that phase of specification and contract when the materials and the methods of work are stated in detail, and to which the contractor must conform absolutely, the engineer and the municipality assuming the risk, if any, of the results obtained being entirely satisfactory. Such specifications and contract may not always secure the lowest unit price, but are more likely to secure the best results. The alternate plan of specifications, is to state the end desired, are general in character, and leave it to the contractor to originate and follow methods based on his own knowledge and experience, to secure the results desired. Circumstances and conditions will generally decide which of these two methods it is best to adopt. When specifications are written up, which are an amalgamation of these two plans, the engineer specifying in detail the material and methods of work, and adding a "rider" to the effect that the contractor will be held responsible for the results, such practice is not fair to the contractor, and with the result that the contractor may accept such contract and specifications with mental reservations. He expects to complete the contract, somehow or somehow, and get his pay for it, omitting or ignoring such parts as do not suit or which he thinks are too rigorous and unfair. The results are generally unsatisfactory. As for the detailed specifications for street work, in this book the author has endeavored to make them fair and just, to require of the contractor no impracticable or indefinite service, or the assumption of risks other than those fairly involved in the business conduct of the work. The book is well worth the careful study of engineers engaged in street or roadway work.

TEACHERS' MANUAL OF BIOLOGY. A hand-book to accompany "Applied Biology" and the "Introduction to Biology," by M. A. and A. N. Bigelow. Maurice A. Bigelow, Columbia University. The Macmillan Company, New York, 1912. 113 pp. 5x7½ in. Cloth bound. Price 40c.

The present day high school course generally devotes a portion of the student's time to biology, and a good many excellent textbooks have been published. This little book is more particularly for the benefit of the teacher, to give hints and references to other works, in amplification of Bigelow's Applied Biology and with some instructions in manipulation and experiments, as assistance in class room or laboratory work.

As stated in the title, this manual is intended for the teacher who uses the Applied Biology, and is similarly divided into numbered sections, which correspond to the same subdivision in the textbook. It is particularly useful, as giving the teacher hints as to what to do and how, in laboratory work and to create or foster an interest in the subject in the pupils. There are many references through the book to other publications, as those issued by the Department of Agriculture, the Farmers' Bulletins, sundry scientific periodicals, besides a list of standard textbooks.

The book seems to be admirably adapted to its purpose, an aid to

teachers who have been but superficially instructed in biology and yet must make a show of knowledge to hold their positions in the schools, and carry forward their classes.

ASPHALT CONSTRUCTION FOR PAVEMENTS AND HIGHWAYS. Clifford Richardson, Mem. Am. Soc. C. E. McGraw-Hill Book Co., New York, 1913. 4 $\frac{1}{4}$ x 6 $\frac{3}{4}$ in., flexible leather, 155 pp., including index. Illustrations and tables in the text. Price \$2.00.

This is a Pocket Book for Engineers, Contractors and Inspectors, well arranged and containing much valuable information. The book opens with an introductory, giving some of the fundamentals of good sheet asphalt pavement, laying down the purposes and objects of specifications, and indicating some of the changes in practice in construction that experience has proven desirable.

Chapter II treats of Broken Stone, which is of much importance. The next chapter takes up the subject of Foundation, of very great consequence in road construction. The costly surface will be of little value, if the foundation of the roadway is defective. As this constitutes the greatest bulk of the road material, the author shows what modifications or substitutions may be used. Next to the foundation comes The Intermediate Course, which consists of broken stone with an asphaltic bituminous binder. The stone is to be heated (and not too hot) to enable the binder to flow and coat the surfaces of all the broken stone. Tables show the proportion of components of this course according to the practice in different cities. Chapter V is devoted to the subject of Mineral Aggregate, and particularly to the sand, with tables of sands used in different places.

Native Bitumens, Their Physical Properties and Chemical Characteristics, is the subject of Chapter VII, while the next chapter treats of Fluxes, which are of much importance in working with asphalts. Chapter X treats of Surface Mixtures, with proportions of bitumen and varying sands, as practiced in many cities. The better life of some surface mixtures over others, is revealed by a study of the proportions of the component parts. This chapter is full of valuable suggestions. A valuable part of this chapter on surface mixtures is "Laboratory Rules and Instructions for Plant Foremen and Chemists," and also "General Information" for the same.

In Chapter XI, the subject of Maintenance and Repairs is given due consideration. This is followed by a chapter on "The Plant" and by Chapter XIII on "Work Upon the Street." In conclusion is given "Advice to Engineers, Contractors and Inspectors," "The Laboratory," "Methods for Examination of Bituminous Materials" and "Instructions for Taking Samples and Specimens for Examination." Altogether, the book contains much of value to those connected with the construction of this class of roadways and also to engineers in general who desire to have at least an intelligent comprehension of the subject.

TRANSMISSION LINE CONSTRUCTION—METHODS AND COSTS. By R. A. Lundquist, E. E., Consulting Engineer. McGraw-Hill Book Co., New York, 1912. Cloth; 6 by 9 in.; pp. 295, including index; many illustrations. Price \$3.00 net.

The table of contents shows that the book is divided into thirteen chapters. The heading of each chapter would indicate that a very thorough and exhaustive treatment of this subject was to be made, and such is the case as far as the present-day standard practice is concerned, although the author does not go into any mathematical discussion; in fact, he states in the preface that "no attempt has been made to cover the electrical and mechanical calculations involved." Therefore the theorist might not say that an "exhaustive treatment" had been made of this subject. It is this very lack of mathematical discussion that makes the book refreshing, and is to be recommended to the construction man and the busy engineer who wish to keep up with the present-day practice.

The author begins by outlining the method of doing the preliminary work which comes in connection with planning a transmission line. Several chapters are devoted to a comparison of the advantages, disadvantages, and special suitability of one type of construction over another.

The book is well arranged. The print is large and good. The many illustrations are clear cut and add much to the text, although some are familiar to the engineer on account of being reproductions of cuts from trade catalogues.

All through the book the author gives detailed labor and material costs for the different parts of the work, and has devoted quite a few pages to compiling the total and segregated costs of a number of well-known transmission lines. A very complete review is given of each line under discussion, so that the cost really means something to the reader, and with the data given he can intelligently use the information for his own purpose.

W. F. C.

LIBRARY NOTES

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MISCELLANEOUS GIFTS.

Ohio State University:

Nathaniel Wright Lord, A Memorial. Bds.

United States Steel Corporation:

Bureau of Safety, Relief, Sanitation and Welfare. Bulletin No. 3 Pam.

A. N. Johnson, M. W. S. E.:

Contract Form and General Specifications for Bridge Work, Illinois Highway Commission.

General Specifications for Concrete Road Construction.

General Specifications for Bituminous Macadam Road Construction. 3 pams.

J. B. Henderson, Brisbane, Australia:

The Goulburn Weir and its Dependent System of Works, Descriptive Memo. Folio.

T. L. Condon, M. W. S. E.:

Akme System Girderless Floor Construction. Pam.

McGraw-Hill Book Co.:

Air Compression and Transmission, Thorkelson. Cloth.

Asphalt Construction for Pavements and Highways, Richardson. Cloth.

Specifications for Street Roadway Pavements, Whinery. Cloth.

Principles of Irrigation Engineering, Newell and Murphy. Cloth.

Universal Portland Cement Co.:

Good Roads Year Book, 1913. Cloth.

P. Blakiston's Sons & Co.:

Liquid Air, Oxygen, Nitrogen; Georges Claude. Cloth.

W. W. Curtis, M. W. S. E.:

Water Supply & Irrigation Paper No. 3. Pam.

Proposed Plan for Sewerage System, Providence, R. I., 1884. Pam.

Rochester, N. Y., Annual Reports Executive Board, 1888-9, 1890. 2 pams.

John M. Sweeney, M. W. S. E.:

54 numbers Journal, American Society of Mechanical Engineers.

8 numbers Journal, Western Society of Engineers.

Sundry Pamphlets.

B. B. Boyer:

The Transportation Exhibits, World's Columbian Exposition, 1893.
Cloth.

William S. Franklin,

Barry MacNutt,

Rollin L. Charles:

An Elementary Treatise on Calculus, Franklin, MacNutt and Charles.
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EXCHANGES.

Massachusetts Board of Railroad Commissioners:

44th Annual Report, 1912. Cloth.

Colorado Agricultural College:

Annual Register, 1913-14. Pam.

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16th Biennial Report, 1911-12. Cloth.

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Year Book, 1912. Cloth.

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Geology and Economic Resources of the Larder Lake District,
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Reconnaissance Along the National Transcontinental Railway in
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Proceedings, 1912. Cloth.

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First Annual Report, 1912. Cloth.

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The Underground Water Resources of the Coastal Plain Province of Virginia. Pam.

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General Index to Transactions, Vols. 1 to 20. Pam.

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Report, 1910, 11, 12. Pam.

Ohio Society of Mechanical, Electrical and Steam Engineers:

Journal, Vol. 5, No. 2. Pam.

GOVERNMENT PUBLICATIONS.

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Water Supply and Irrigation Papers Nos. 259, 293, 297, 300, 310, 311, 313, 316. Pams.

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COLUMNS.

O. H. BASQUIN, M. W. S. E.

Presented December 9, 1912.

When one wishes to be reassured as to the state of his health, he is likely to have a thorough examination made of his heart, lungs, and other vital organs. He might go to a mortuary table and find that persons of his age, or, possibly, of his slenderness ratio, generally live ten or fifteen years longer. But such general information would not give him as much confidence as the examination of his special case. In the design of a beam one considers the maximum stresses which, according to a simplified theory, will be present in the beam when its loads have reached certain values. But in the design of a column one consults the mortuary table of column tests, or certain formulas derived therefrom, and proceeds to design the section without very much regard to the manner in which the loads may be applied to that particular column.

It is perhaps too much to expect that engineers will abandon the empirical method of the design of columns. The present method is easy of application, the formulas are perfectly definite, and, so long as the formulas are used intelligently, one feels that the responsibility for the strength of any particular column is thrown upon the profession at large or, perhaps, upon the prominent engineers who sanction the use of these formulas. The alternative method is more troublesome in application. It involves an estimate of the maximum values of certain quantities little understood, and the responsibility for strength rests with the designer alone.

Although secondary stresses are rarely calculated for bridges of ordinary proportions, still one feels that a bridge design is likely to be safer if the designer is somewhat familiar with the subject of secondary stresses. So, also, in the design of columns; a knowledge of the maximum stresses likely to be present in those columns may lead to better design, and, in certain special instances, it may be worth while to apply the method in order to make sure that the sections given by the standard formulas are sufficient.

The formulas for the stresses and the deflections of eccentric-

ally-loaded columns are fairly well known,*¹ and while these will be stated, they will not be derived. Our principal attention will be directed to a discussion of how it may happen that a column which is built for an axial load may actually or virtually receive an eccentric load. Inasmuch as this inquiry is quite independent of whether the columns are made of steel or of wrought iron, and since tests of steel columns are not available in much variety, illustrations will be drawn from tests made at the Watertown Arsenal upon wrought iron columns in the years 1881, 1883 and 1884.

These particular tests are well suited to our purpose for two reasons: first, because the deflections of each column are reported both for the horizontal and for the vertical plane, and, second, because the gauge line, along which compression was measured, did not extend to the pin plates, and thus the compression recorded is that which was in the web of the column rib and does not include the slipping which frequently occurs in the riveted joints between the web and the pin plates.

In Fig. 1 results are shown for two columns whose loads were closely axial. All columns were tested in a horizontal position and suitably counterweighted in the vertical plane. Column 342-1884 had flat ends; its deflections in the vertical plane are indicated by small circles, and its deflections in the horizontal plane, by small crosses. It will be seen that no deflection as large as 0.01 in. occurred until the unit stress exceeded 29,000 lb. per sq. in. Column 4-1881 had 3½-in. pins; deflections parallel to the pins are indicated by small circles, while deflections in a plane perpendicular to the pins are indicated by small crosses. With the exception of a small deflection when the load was about 1,000 lb. per sq. in., the deflections do not appear until the load passes 23,000 lb. per sq. in.; and, oddly enough, the deflections shown have the same numerical values both parallel to the pins and at right angles to them. It may be noted that, although these two columns have about the same slenderness ratio in the horizontal plane, the column with pin ends is fully as strong, under a truly axial load, as the column with flat ends.

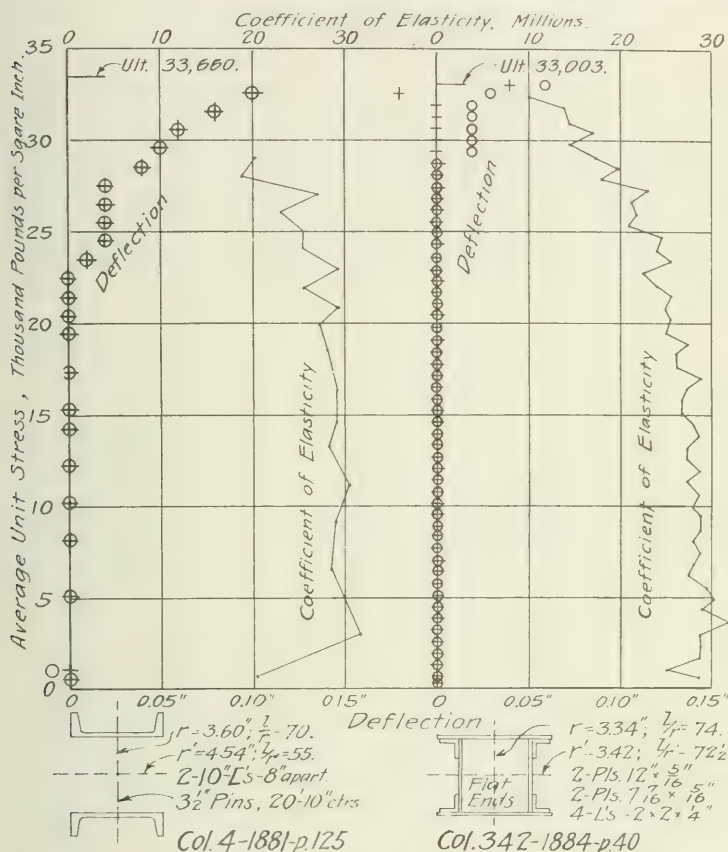
Instead of showing a compression-stress curve, each increment of unit stress has been divided by the corresponding increment of unit strain, and this ratio has been plotted as the coefficient of elasticity. While this method of indicating the compression has the disadvantage of making the coefficient of elasticity appear to vary in a rather erratic manner, it has the excellence of sharply indicating every lack of proportionality in the stress-strain relation. Thus, in both columns of Fig. 1, the coefficient of elasticity ap-

*1—Boyd's *Strength of Materials*, p. 181.

Morley's *Strength of Materials*, p. 249.

Heller's *Stresses in Structures*, p. 172.

pears to decrease as the stress increases beyond about 15,000 lb. per sq. in. As it is quite probable that this low proportional limit



The loads on these columns were evidently closely axial

Fig. 1.

is due to overstrain*² incident to punching, straightening, and riveting, it would be instructive to have tests made upon columns, some

*²—With regard to tensile tests upon specimens cut from steel beams, Prof. Hancock says: "Overstraining structural shapes lowers the elastic limit of the metal, but not permanently, the elastic limit returning to and above its original value when the material is allowed to rest." *Proc. Am. Soc. Testing Materials*—1911.

In his recent tests upon large steel columns, Mr. James E. Howard found a low proportional limit. He remarks: "It is, indeed, a matter of doubt whether any work of magnitude, involving the use of structural members of the kind under consideration, can be cited as an example in which no part thereof is strained beyond the elastic limit of the material." *Proc. Am. Soc. C. E.*, Feb., 1912.

of which have been fabricated just before testing, while others have left the shop a year or more previously.

FORMULAS FOR STRESSES AND DEFLECTIONS OF ECCENTRICALLY-LOADED COLUMNS.

Let the section of the column have the form shown in Fig. 2, its principal axes being OY and OZ . Let r_y be the radius of gyration about the Z axis and r_z the radius of gyration about the Y axis. Let the average unit stress be p_0 , i. e., this is the whole load divided by the whole area. Let the line of action of this load be normal to the section and intersect it at a point whose coördinates are e_y and e_z . If the column is so short that its deflection may be neglected, the

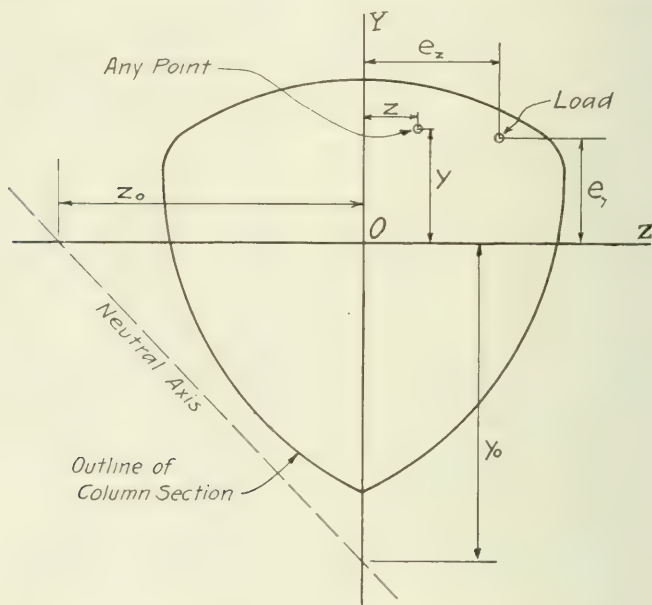


Fig 2.

compressive unit stress, p , at any point whose coördinates are y and z , is

$$p = p_0 \left(1 + \frac{e_z z}{r_z^2} + \frac{e_y y}{r_y^2} \right) \dots \dots \dots \text{Eq. 1.}$$

Let the column have length l , and let its ends be free from constraint except that each end carries a single load whose line of action has the same eccentricities, e_y and e_z , at both ends. The deflection will be greatest at the middle of the column, and its components

parallel to the Y and Z axes may be represented by Δ_y and Δ_z , respectively. In the section at the middle of the column, the compressive stress, p , at any point whose coördinates are y and z is,

$$p = p_0 \left(1 + \frac{(c_z + \Delta_z) z}{r_z^2} + \frac{(c_y + \Delta_y) y}{r_y^2} \right) \dots \dots \dots \text{Eq. 2.}$$

The expressions for the deflections are

$$\left. \begin{aligned} \Delta_z &= c_z \left\{ \sec. \left(\frac{l}{2r_z} \sqrt{\frac{p_0}{E}} \right) - 1 \right\} \\ \Delta_y &= c_y \left\{ \sec. \left(\frac{l}{2r_y} \sqrt{\frac{p_0}{E}} \right) - 1 \right\} \end{aligned} \right\}^{*3} \dots \dots \dots \text{Eq. 3.}$$

It is customary to let θ represent the function $\frac{l}{2r} \sqrt{\frac{p_0}{E}}$, and we

may call it the Eulerian angle. If we express the average stress p_0 in units of 1,000 lb. per sq. in., and take 29,500,000 lb. per sq. in. as the coefficient of elasticity, the Eulerian angle may be expressed in degrees as,

$$\theta = \frac{l}{6r} \sqrt{p_0} \quad^{*4}$$

The sections commonly used at the present time for steel columns have a rectangular form with four projecting corners. In

*3—These expressions do not take into account the deflection due to shear. The complete expression is given by Henry S. Prichard in *Engineering News*, Feb. 25, 1909, and may be written thus:

$$\Delta = e \left[\sec. \left(\frac{l}{2r} \sqrt{\frac{p_0}{E} \frac{1}{\sqrt{1-A p_0 t}}} \right) - 1 \right]$$

in which A is the sectional area of the column and t is the deflection in unit length caused by unit shearing force. The term $A p_0 t$ is, therefore, the deflection in unit length which would be caused by a shear equal to the whole load that the column carries. Whenever this deflection is small in comparison with unity, the shear may be neglected, as will be done in the tests to be cited in this paper. At a load of 20,000 lb. per sq. in., the error thus introduced into the value of the Eulerian angle is in some cases as large as 1½%.

*4—It may be worth while to note that this value is readily obtained by use of the slide rule, thus: After setting one end of scale C at $\frac{l}{6r}$ on scale D , if one sets the slider at p_0 on scale B , he may read the value of θ in degrees from the slider on scale D .

such a case the maximum compressive stress will occur in the extreme corner of the quadrant which contains the line of action of the load. In some sections, such as circular ones, there may be some difficulty in picking out the point having the maximum stress. In such a case the direction of the neutral axis may be determined, and the point of maximum stress located as the one farthest distant from the neutral axis. Thus, in Fig. 2, let the neutral axis cross the Y and Z axes at distances y_0 and z_0 , respectively, from the origin. In the section at the middle of the column, the values of y_0 and z_0 are,

$$\left. \begin{aligned} y_0 &= \frac{r_y^2}{c_y + \Delta_y} \\ z_0 &= \frac{r_z^2}{c_z + \Delta_z} \end{aligned} \right\} \dots \dots \dots \text{Eq. 4.}$$

EXAMPLE.

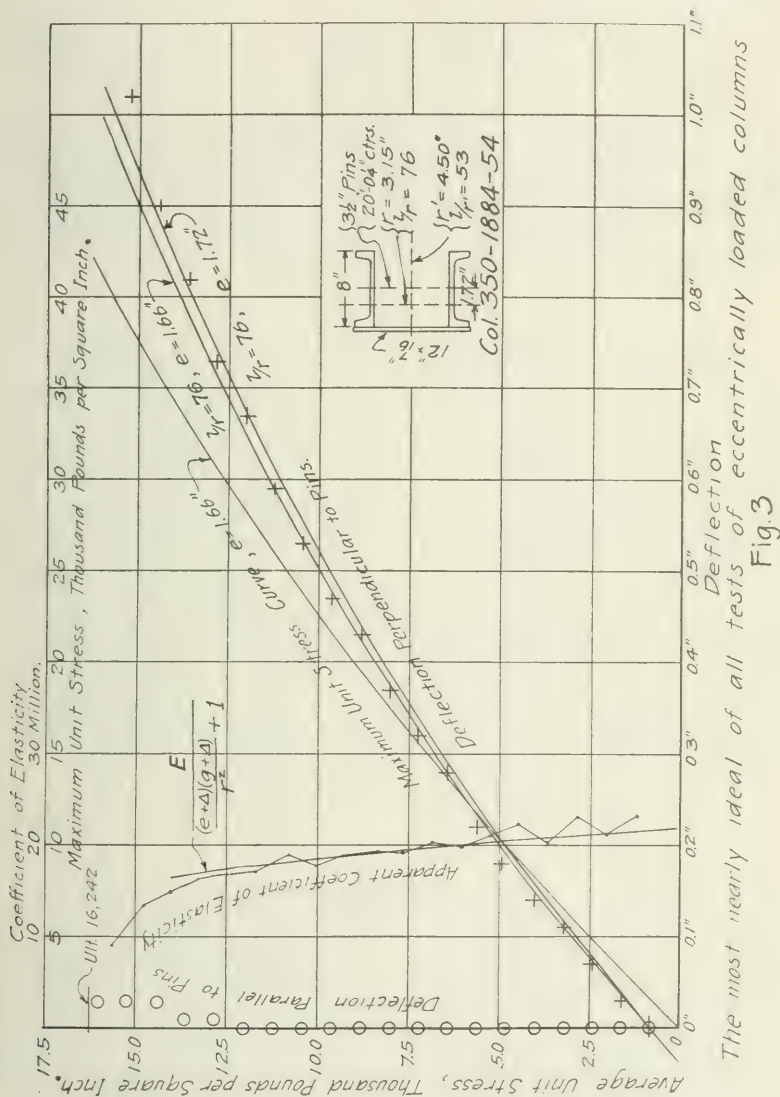
The results given by the test of column 350-1884 correspond closely with the theoretical discussion outlined above. Deflection parallel to the pins did not occur until the proportional limit had evidently been passed. The axis of the pin hole was 1.72 in. from the gravity axis of the section as calculated from the actual dimensions reported. The theoretical deflection curve for an eccentricity of 1.72 in. and a coefficient of elasticity of 28,000,000 lb. per sq. in. is shown as the lower curve on the diagram, and the deflections perpendicular to the pins are close to this curve. But they are somewhat closer to the other curve shown for which the eccentricity has been taken as 1.66 in. In calculating the maximum unit stress,*⁵ it has been assumed that the actual eccentricity was 1.66 in., that the coefficient of elasticity is 28,000,000 lb. per sq. in., and that Hooke's law holds up to the extreme load; the last assumption, of course, is not warranted for an average unit stress in excess of about 12,000 lb. per sq. in.

It will be noticed that for this column the apparent coefficient of elasticity is about 20,000,000 lb. per sq. in. instead of 28,000,000. This may be accounted for from the fact that the gauge line was not on the gravity axis of the column. Thus, considering a simple column whose only eccentricity is e_z in the Z plane, let us suppose that compression is measured along a gauge line laid off at a distance, g_z , from the Y plane. If the average unit stress, p_0 , over the section is increased by a small amount, $d p_0$, the increment of unit

*5—Read the maximum unit stress at the top of the diagram for given average unit stress read at the left side, thus for 12,500 average unit stress. the maximum unit stress is about 29,300 lb. per sq. in.

stress along the gauge line will be $d p_0 \left(1 + \frac{(e_z + \Delta_z) g_z}{r_z^2} \right)$

If E is the true coefficient of elasticity, the increment of unit strain



The most nearly ideal of all tests of eccentrically loaded columns
Fig. 3

along the gauge line will be $\frac{d p_0}{E} \left(1 + \frac{(e_z + \Delta_z) g_z}{r_z^2} \right)$

and the apparent coefficient of elasticity, E' , will be the increment $d p_0$ of average unit stress divided by the real increment of unit strain, i. e.,

$$E' = \frac{E}{1 + \frac{(e_z + \Delta_z) g_z}{r_z^2}} \quad \div \quad \text{Eq. 5.}$$

The values of E' for column 350-1884 have been calculated from this equation, and the curve obtained is seen to correspond fairly well with the observed values of the apparent coefficient of elasticity. On the whole, we may say that this test shows a satisfactory agreement between theory and experiment.

BENT COLUMNS.

While an ideal column is assumed as initially straight, it is probably rare that the middle of a column is in line with its ends to within a few hundredths inches. In this connection, Mr. R. S. Chew^{*6}, says: "Those in charge of one of the leading testing bureaus state that commercial columns 30 ft. long, fabricated under the best conditions, have seldom less than $\frac{1}{4}$ in. of kink or bend in them." The report of the Royal Commission upon the Quebec bridge (p. 67) contains the following: "The lines of the several ribs in the chords are known to have been wavy to the extent of from $\frac{1}{2}$ in. to $\frac{3}{4}$ in. (see evidence), but errors of this size and kind do not appear to have been considered a cause of anxiety. The existence of these wavy bends had been noticed by the shop inspectors and had been reported both to Mr. Szlapka and to Mr. Cooper."

If the axis of a column is initially bent so that under no load it follows a sine curve whose greatest departure from a straight line is e , the deflection under central load will be,

$$\Delta = \frac{e}{\frac{\pi^2 E r^2}{p_0 l^2} - 1} - e \quad \text{Eq. 6.}$$

Believing that crookedness is the chief imperfection of columns, a recent writer^{*7} has used this equation as the basis of a new column formula. We shall see that columns are subject to several other imperfections besides crookedness, and, inasmuch as the deflection given by Equation 6 is slightly smaller than that of the

^{*6}—*Proceedings Am. Soc. C. E.*, May, 1911.

^{*7}—H. V. Hutt, *Engineering*, July 26, 1912, p. 113.

†For correction see p. 497.

straight column carrying an eccentric load, it seems better to regard a bend in a column as an eccentricity in a straight column, the latter having the same length and cross-section as the bent column. Thus in Fig. 4 we replace the bent column, *a*, by the straight column, *b*.

That the ends of a column may be "fixed" two conditions of restraint are necessary: first, each end of the column must be kept parallel to its initial position, and, second, neither end must move in a plane perpendicular to the axis. Consider a bent column with fixed ends, *c*, Fig. 4. Let the length be L and its maximum departure from a straight line be $2e$. The stresses in such a column will be the same as those in a simple bent column whose length is $l = \frac{1}{2} L$ and whose bend is $e = \frac{1}{2} (2e)$; this column is shown at *d*, Fig. 4, and we have already agreed to replace this column by

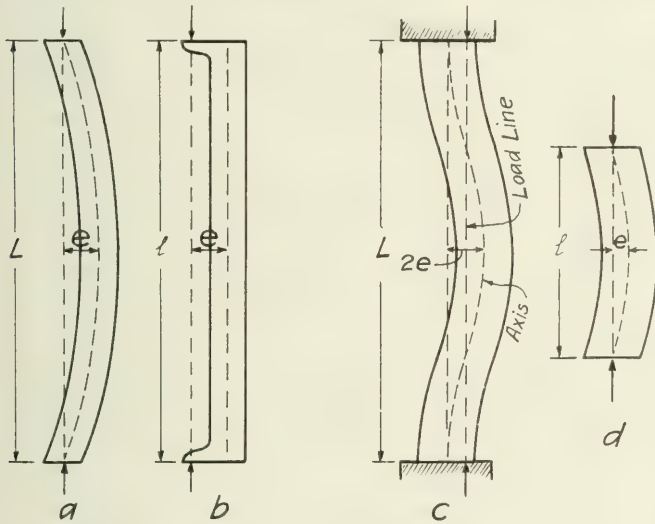


Fig. 4.

a straight one whose length is $l = \frac{1}{2} L$ and whose eccentricity is e . The deflections of the bent column with fixed ends will be double those of the short column.

BUCHANAN'S COLUMN TESTS.

About five years ago Mr. C. P. Buchanan published*⁸ the results of certain tests of columns made for the Pennsylvania lines west of Pittsburgh. The loads were applied through pins, which in three tests were supposed to be at the axis of the columns, and in

*⁸—*Engineering News*, Vol. 28, No. 26, Dec. 26, 1907.

the other tests were given an intentional eccentricity. The deflections of these columns, both perpendicular to the pins and parallel to them, are given in the report, and on investigation it is found that these deflections are not, in general, precisely such as would

BUCHANAN'S COLUMN TESTS								
	NUMBER OF TEST	SLENDERNESS RATIO	RADIUS OF GYRATION	DISTANCE TO EXTREME FIBER	INTENDED ECCENTRICITY	INTENDED ECCENTRIC RATIO	ACCIDENTAL ECCENTRICITY	ACCIDENTAL ECCENTRIC RATIO
PERPENDICULAR TO PINS	5	42	5.55"	9.22'	0.62"	0.18	+0.12"	0.04
	6	36	4.88"	8.02"	0.52"	0.17	+0.03"	0.01
	7	39	5.69"	8.74"	0.48"	0.13	+0.10"	0.03
	8	39	5.69"	8.74"	0.48"	0.13	+0.73"	0.20
	9	97	3.10"	6.25"	0"	0	0.07"	0.05
	10	46	6.34"	10.27"	0.62"	0.16	+0.04"	0.01
	11	46	6.33"	10.29"	0.62"	0.16	+0.03"	0.01
	12	29	5.65"	9.09"	0.68"	0.19	+0.67"	0.19
	13	42	5.80"	8.44"	0.39"	0.10	+0.44"	0.12
	14	40	4.71"	8.04"	0.95"	0.34	+0.12"	0.04
	15	38	6.51"	9.48"	0.38"	0.08	+0.13"	0.03
	16	43	6.44"	10.34"	0.74"	0.18	-0.01"	0.00
	17	45	3.72"	5.10"	0"	0	0.40"	0.15
	18	34	7.29"	10.10"	0.64"	0.12	+0.72"	0.13
	19	35	7.20"	10.10"	0"	0	0.18"	0.04
					Mean		0.25"	0.07
PARALLEL TO PINS	5	34	7.07"	9 $\frac{3}{4}$ "	0"	0	0.51"	0.10
	6	30	5.78"	8 $\frac{1}{4}$ "	0"	0	0.20"	0.05
	7	32	7.04"	9 $\frac{3}{4}$ "	0"	0	1.08"	0.21
	8	32	7.04"	9 $\frac{3}{4}$ "	0"	0	2.54"	0.50
	9	62	4.81"	5 $\frac{1}{2}$ "	0"	0	0.97"	0.23
	10	36	8.01"	11 $\frac{1}{4}$ "	0"	0	1.65"	0.20
	11	36	8.01"	11 $\frac{1}{4}$ "	0"	0	0.97"	0.17
	12	23	7.00"	9 $\frac{3}{4}$ "	0"	0	0.38"	0.08
	13	35	6.93"	9 $\frac{3}{4}$ "	0"	0	1.54"	0.31
	14	30	6.28"	8 $\frac{3}{4}$ "	0"	0	0.71"	0.16
	15	35	7.08"	10 $\frac{3}{4}$ "	0"	0	2.41"	0.52
	16	36	7.80"	10 $\frac{3}{4}$ "	0"	0	1.74"	0.31
	17	22	7.72"	8 $\frac{1}{2}$ "	0"	0	2.19"	0.31
	18	32	7.74"	10 $\frac{3}{4}$ "	0"	0	0.35"	0.06
	19	32	7.74"	10 $\frac{3}{4}$ "	0"	0	0.42"	0.08
					Mean		1.18"	0.22

Fig. 5.

be given, according to the above theory, by the same columns having the eccentricities intended. Professor C. T. Morris has suggested*⁹ that, since the deflections are accurately known, one may

*⁹—*Engineering News*, Vol. 66, No. 18, Nov. 2, 1911.

use them in estimating the actual eccentricities present in these column tests. The difference between the actual eccentricities and the intended eccentricities may be called "accidental eccentricities," and these latter are the ones to which all columns are subject. This method, therefore, gives us in one number, or perhaps two numbers, an estimate of the total imperfections to which each column as a whole was subject.

Professor Morris has applied this method to the tests reported by Buchanan, and the table given as Fig. 5 is made up from his results. The plus sign (+) before a value of the accidental eccentricity given in the table indicates that the accidental eccentricity is an increase of the intended eccentricity, and it will be noticed that, out of sixteen tests, fifteen of them show a real eccentricity larger than that intended. The mean value of the accidental eccentricities perpendicular to the pins is 0.25 in., and its maximum value in these tests is nearly 0.75 in. Since there are three of these large values of the accidental eccentricity, the theory of probability indicates that, in a larger series of similar tests, a few columns would be likely to have accidental eccentricities exceeding 0.75 in. in value.

In this table there is given for each column the distance from the gravity axis to the most distant fiber which is under greatest

stress and this distance is denoted by the letter c . The ratio $\frac{e c}{r^2}$

is one in which we shall be interested; its value for each column is given in this table and it is called the "eccentric ratio"; the corresponding ratio for the accidental eccentricity is called the "accidental eccentric ratio," and this is given in the last column of the table.

For the plane perpendicular to the pins, the mean value of the accidental eccentric ratio is 0.07. Since there are five rather large values of this ratio, we may expect that, in a series of tests comprising a larger number of columns, some columns will show an accidental eccentric ratio somewhat larger than 0.20.

In the plane parallel to the pins the table shows much larger values*¹⁰ both for the accidental eccentricities and for the accidental eccentric ratios. This indicates that, in the plane of the pins, it is much more difficult to attain any desired distribution of the column load than it is in the plane at right angles to the pins.

*10—It will be shown later that, in the plane parallel to the pins, of the above tests Nos. 5, 8, 9, 14, 16, and 17, the method used by Professor Morris is not strictly applicable and that the accidental eccentricities given above are somewhat too large.

SOURCES OF ACCIDENTAL ECCENTRICITY.

The above method, suggested by Morris, gives us some idea of the magnitude which the accidental eccentricity is likely to assume. This method is, however, a rather blind one inasmuch as the circumstances which lead to the accidental eccentricity are not disclosed. This accidental eccentricity may arise in a number of different ways, and while it is not likely that any one column of the first hundred, that might be examined, would combine the maximum values of these imperfections, it is probable that one or two of the many columns that are fabricated every year do represent extreme combinations of these imperfections. It seems advisable, therefore, to consider somewhat in detail the imperfections to which a column may be subject.*¹¹

Bends.—The matter of crookedness has already been discussed. It is generally specified that "built members shall be free from twists, bends, or open joints," but this is not sufficiently definite. What may appear as a straight column to an inspector may be regarded as a bent column by the designer. Would it not be better to standardize the crookedness which may pass inspection? The limit might be stated as 1, 16 in. for every five feet of length, or whatever amount may be agreed upon as conforming to good practice. Such a statement of requirements would enable the designer to work more intelligently.

Variation of Section.—We already have the requirement that "a variation in cross-section or weight of each piece of steel of more than $2\frac{1}{2}\%$ from that specified will be sufficient cause for rejection." A variation in the section of the parts of a column may be such as will displace the center of gravity. The maximum change will be obtained by assuming all the parts on one side of an axis as $2\frac{1}{2}\%$ heavy and all other parts light by the same ratio. In this case the displacement of the center of gravity will be about $2\frac{1}{2}\%$ of the distance between the gravity centers of the two halves of the column section. In columns whose sections are made up of channels, this effect will be small in the plane parallel to the webs, but in columns of I section it will generally be largest in that plane. In column 4-1881 the maximum effect would be 0.24 in. in the plane perpendicular to the webs; in column 350-1884 it would be only 0.06 in. in

*¹¹—Mr. R. S. Chew (*Proc. Am. Soc. C. E.*, May, 1911) classifies imperfections thus:

First.—Initial stresses in material due to manufacture.

Second.—Variation in strength of component parts, of section.

Third.—Crookedness of component parts.

Fourth.—Crookedness of whole member.

Fifth.—Local stresses due to details and shop work.

Sixth.—Accidental eccentricity.

Seventh.—Deflection caused by the foregoing imperfections."

the plane parallel to the webs, and 0.14 in. in the plane perpendicular to them.

Variation of Elasticity.—If the different parts of a column section have different coefficients of elasticity, this variation may be such as to displace the effective center of gravity with respect to the geometric center of gravity.

The coefficient of elasticity is generally thought to be a most reliable constant, having a value lying between 27,000,000 and 28,000,000 lb. per sq. in. for wrought iron, and a value lying between 29,000,000 and 30,000,000 for steel. After quoting the results of various tests of wrought iron, Professor Burr remarks:^{*12} "In the aggregate, the values run from 25,000,000 to 37,209,300 lb., giving a variation of 50% of the lowest amount. The latter value is too high and is doubtless due to some error in observation." With regard to steel, he refers to results of tests in which the extreme values of the coefficient of elasticity are 24,360,000 and 30,890,000 lb. per sq. in.

In a comparatively recent paper, Mr. James E. Howard incidentally shows the following results of tensile tests upon certain samples of plates and angles which were used in the fabrication of columns tested by him, and reported^{*13} to the American Society of Civil Engineers.

Plates.		Angles.	
Coefficient of Elasticity.	Melt.	Coefficient of Elasticity.	Melt.
23,440,000	16,266	26,640,000	24,879
23,440,000	16,266	27,000,000	23,982
24,270,000	6,542	27,270,000	23,982
24,560,000	6,542	27,790,000	23,982
24,560,000	6,542	28,120,000	24,879
24,660,000	6,542	29,760,000	23,982
24,830,000	6,542	30,060,000	23,982
24,870,000	6,542	30,200,000	24,879
24,950,000	6,542	30,330,000	23,932
25,290,000	21,943	31,730,000	23,982
25,820,000	16,266	32,080,000	23,982
26,420,000	16,266	32,440,000	23,982
26,790,000	16,266	32,450,000	23,982
26,800,000	6,542	32,570,000	24,879
27,000,000	6,542	32,580,000	23,982
27,150,000	6,542	32,600,000	23,982

*12—Burr: *Elasticity and Resistance of the Materials of Engineering*, p. 210.

*13—*Proc. Am. Soc. C. E.*, Feb., 1911.

27,290,000	16,266	32,970,000	23,982
28,210,000	12,266 (?)	33,820,000	23,982
33,640,000	21,943	34,040,000	23,982
33,660,000	16,266	36,860,000	23,982
Mean 26,380,000		Mean 31,060,000	

Shall one conclude from these tests that the coefficient of elasticity is subject to a variation of 20% either above or below 30,000,000 lb. per sq. in.? Shall one also conclude that its average value for angles is 15% or 20% greater than its value for plates? It is probably safe to say that the profession will not accept such conclusions without much more evidence. But on the other hand it would not be the part of wisdom to adhere to the common belief in the almost constant value of this coefficient for all samples of structural steel. There is great need of extensive experimental work upon this question. This work requires great care but it does not require an elaborate outlay either for apparatus or for specimens. It is to be hoped that information of this character will not be wanting much longer.

Stresses in a Column Whose Parts Have Different Coefficients of Elasticity.—Let us consider a column whose section is made up of areas A_1, A_2, A_3 , etc., whose centers of gravity are at distances a_1, a_2, a_3 , etc., from the gravity axis of the whole section. Let the coefficient of elasticity of these various areas be E_1, E_2, E_3 , etc. At first we may consider the column to have truly flat ends and to be loaded in a testing machine, whose compression heads are parallel planes. Under these circumstances the column will have the same unit strain over its whole section; but the unit stresses in the various areas will be different, being proportional to their several coefficients of elasticity. The load carried by this column will have a line of action which does not pass through the gravity axis, but is at a distance, e , from it such that,

$$e = \frac{A_1 E_1 a_1 + A_2 E_2 a_2 + A_3 E_3 a_3 + \text{etc.}}{A_1 E_1 + A_2 E_2 + A_3 E_3 + \text{etc.}} \dots \dots \dots \text{Eq. 7.}$$

Such a column tested under ideal conditions will show no deflection.

If we now assume that the load is applied by means of frictionless pins located on the line of action whose position is given above, this column also will give no deflection. But if the frictionless pins are located at the gravity axis, the column will deflect in much the same way as the simple column with eccentricity, e , and with a uniform coefficient of elasticity. We may use the ordinary expression for the deflection, Equation 3, with the usual value, E , for the coefficient of elasticity, but for accurate work a modified value of the moment of inertia must be used; thus,

$$I = \frac{1}{E} (E_1 I_1 + E_2 I_2 + E_3 I_3 + \text{etc.}) \dots \dots \dots \text{Eq. 8}$$

in which I_1 is the moment of inertia of area A_1 about an axis parallel to the gravity axis, but located at distance, e , from it, with similar definitions for I_2 , I_3 , etc. The value for the stress at any point is

$$p = \frac{p_0 E_{yz}}{E} \left(\frac{(e_y + \Delta_y) y}{r_y^2} + \frac{(e_z + \Delta_z) z}{r_z^2} \right) \dots \dots \text{Eq. 9,}$$

in which E_{yz} refers to the coefficient of elasticity of the material at the particular point in question, and the radii of gyration are derived in the usual way from the moments of inertia as defined above. The coördinates y and z also are referred not to the principal axes of inertia but to the modified axes, distant e_y and e_z from the former.

As a simple illustration, let us take a latticed column made up of two 10-in. channels spaced 6.44 in. apart, back to back. If we assume that the coefficient of elasticity for one of them is 25,000,000, while that of the other is 35,000,000, the effective eccentricity at right angles to the webs is 0.64 in. The proper radius of gyration becomes 3.96 in. instead of 3.91 in.; the deflection of such a column 25 ft. long, with a central load of 10,000 lb. per sq. in., is 0.19 in.; and the maximum unit stress is 11,300 lb. per sq. in. If in this column we replace the latticing by $13 \times \frac{3}{8}$ in. plates whose coefficient of elasticity is 30,000,000, the effective eccentricity is 0.38 in., the deflection is 0.12 in.; and the maximum stress in the channel is only 10,150 lb. per sq. in.; but in the edge of the plates this stress becomes 12,300 lb. per sq. in.

The effect on the stress is thus seen to be comparatively small, if the column section is divided by the gravity axis into two portions, in each of which the coefficient of elasticity is practically constant, although different from that of the other portion. But the effect upon the stress is considerable if, in the portion of the section which has a low average value for its coefficient, there happens to be a small area far removed from the axis, whose coefficient is not low. To provide for this effect, it will generally be better to use Equation 2 in place of Equation 9, for the purpose of estimating the stress in cases of this kind. And it is also to be noticed that the radius of gyration derived from Equation 8 differs so little from the radius of gyration about the gravity axis, that this difference may be neglected in most instances.

With these simplifications, therefore, we may treat a column, whose parts have different coefficients of elasticity, as an ordinary column that has an eccentricity given by Equation 7.

Poor Bearings.—In many cases a column load is eccentric, because the ends of the column do not come to a good bearing over

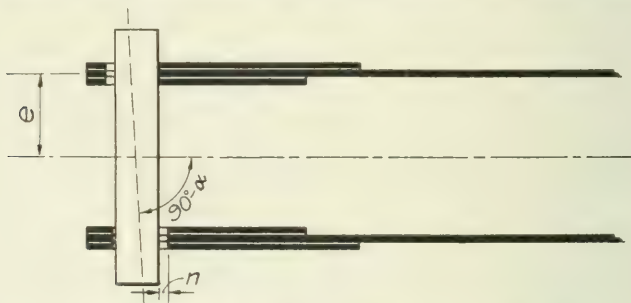
their entire areas until the load has reached a considerable value. This is likely to happen in all kinds of columns, both in structures and in laboratory tests.

Let us consider a column whose eccentricity is confined to the Z plane. At the ends of the column, the inclination of the axis with the line of action of the load is

$$a = c k \tan \left(k \frac{l}{2} \right) \dots \dots \dots \text{Eq. 10,}$$

in which $k = \frac{1}{r} \sqrt{\frac{p_0}{E}}$. Let the column in question have pin ends,

the pins lying in the Z plane. Let the pin plates be at distance $2c$ apart and let the axis of the pin hole make an angle $(90^\circ - a)$ with the axis of the column, the angle between the axes of the two



Section through a Poorly Made Pin Bearing.

Fig. 6.

pin holes being $2a$. When one end of each pin comes to a bearing, let there be a play equal to n at the other end of the pin. This condition is shown in Fig. 6. We have

$$n = 2ca = 2c^2 k \tan \left(k \frac{l}{2} \right) \dots \dots \dots \text{Eq. 11.}$$

Now, if the column comes to a good bearing before the unit stress

becomes large, we may take $\tan \left(k \frac{l}{2} \right) = \frac{1}{2} kl$, so that

$$n = c^2 k^2 l = \frac{c^2 p_0 l}{Er^2} \text{ or}$$

$$p_0 = \frac{nr^2 E}{c^2 l} \dots \dots \dots \text{Eq. 12.}$$

This is the average unit stress at which the column comes to a good bearing on its short side. Since the deflection will be small in comparison with the eccentricity, the *extra* stress due to bend-

$$\text{ing may be taken as } p_e = p_0 \frac{ec}{r^2} = \frac{nEc}{el} \dots \dots \dots \text{Eq. 13,}$$

in which c is the distance of the most stressed fiber from the gravity axis.

As an illustration, let us suppose that the above column is made up of two 10 in. channels weighing 15 lb. per ft., latticed, 6 in. apart back to back. Taking a slenderness ratio of 70, we find, from Equation 12, that the column will come to a good bearing when the load reaches about 160,000 n lb. per sq. in., i. e., a load of 1,600 lb. per sq. in. is required for every 0.01 in. error in the pin holes. From Equation 13 we find that the extra stress due to bending alone is over 2,000 lb. per sq. in. for every 0.01 in. error in the pin holes, making a maximum unit stress of about 3,600 lb. per sq. in. for each 0.01 in. error.

Up to the load at which full bearing is obtained, the column with pin ends deflects in the plane of the pins as a simple column. If the pins are properly supported, it must deflect as a fixed column for greater loads, and the eccentricity which will govern its further action will be quite different from its early value.

In tests of more than one hundred columns made at Watertown Arsenal, about five-eighths of them show a noticeable deflection parallel to the pins for small loads. The deflection, however, does not generally indicate an initial eccentricity equal to the half distance between the pin plates. This may be accounted for in at least two ways: first, there may be a good bearing at one end of a column at the beginning of the test, so that the deflection is caused by the full eccentricity acting at the other end only; or, second, there may be a good bearing between the pins and the pin plates at both ends while there is a certain amount of play between the bolsters, which carry the pins, and the compression heads of the testing machine. For, in many tests, in order to get a good bearing, it was found necessary to insert thin brass strips under one side of one or both bolsters.

Of course, it is quite unlikely that the errors in the pin holes would be equal, and both on the same side of the column. If they were equal and on opposite sides, their presence would not be indicated by the central deflection: In a few tests the early deflection parallel to the pins follows one law and then abruptly changes to another one which it follows for some time before the column

comes to a good bearing at both ends. This may be due to a slight rocking of the column bolsters, or in some cases it may indicate that the column comes to a bearing at one end before it does at the other. In this case the two errors will be on the same side of

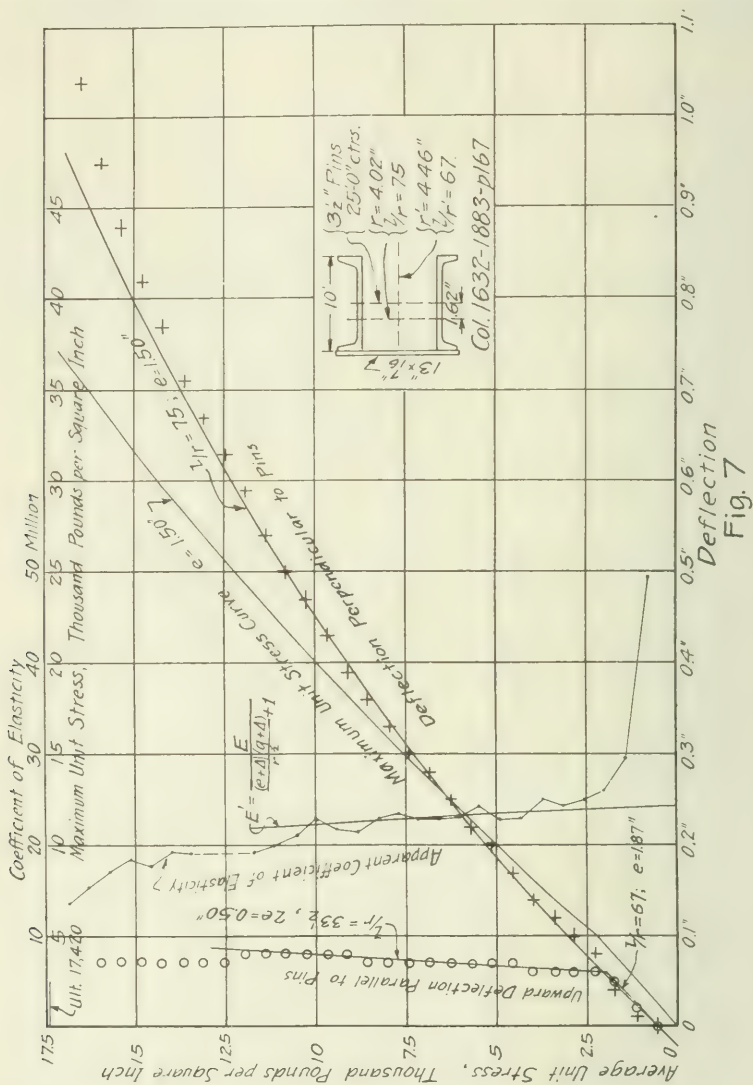


Fig. 7

the column if the eccentricity indicated by the first deflection is greater than that of the second, but on opposite sides if the reverse holds true.

In tests of eighteen columns with flat ends, twelve showed no deflection in either plane for small loads, four showed such deflection in one plane only, while two tests showed such deflection in both planes. This may indicate that a column with flat ends can be fitted to the testing machine so as to give good bearing more easily than a column with pin ends.

Diagrams of Tests.—Tests of columns 1632-1883 and 1633-1883 are quite similar to that of 350-1884. In the plane perpendicular to the pins the accidental eccentricity is about 0.12 in. in

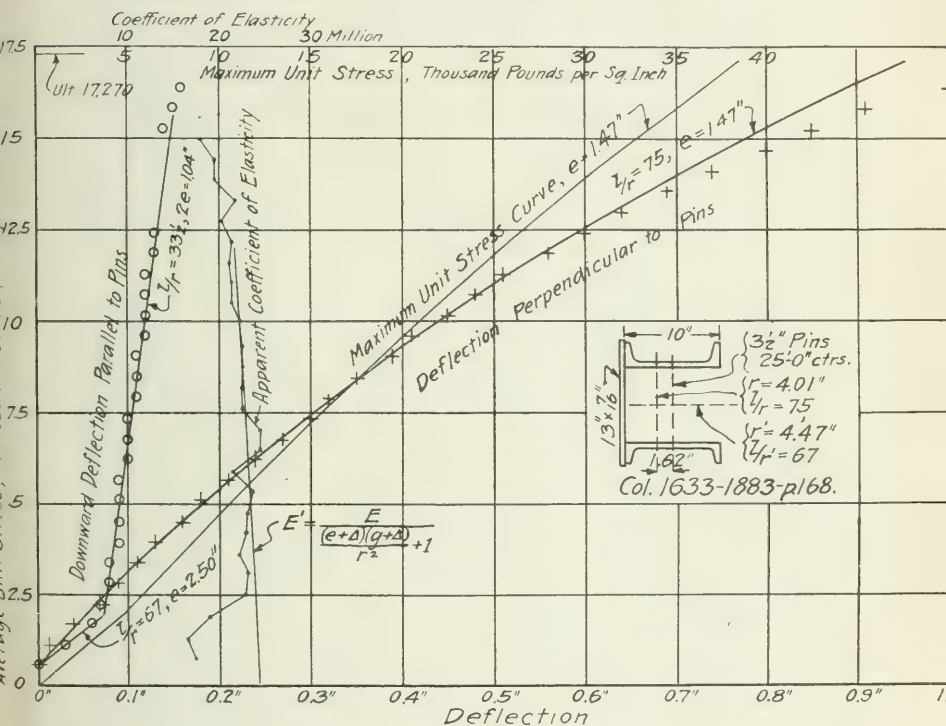


Fig. 8.

No. 1632 and about 0.15 in. in No. 1633. In each of these three cases the effective eccentricity is smaller than the intended eccentricity, making the accidental eccentricity negative. This result is opposite to the results of Buchanan's tests, in which the accidental eccentricity is positive, with only one exception.

In the plane of the pins, the early deflection showed an eccentricity of 1.87-in. in column 1632 and 2.50-in. in column 1633. The former column deflected upward and the latter downward; this accounts for the opposite effects seen in the value of E' for

small loads. The curve shown for E' does not take into account any eccentricity parallel to the pins. If we use the above eccentricities in that plane, the value of E' for small loads will be about 41,000,000 for No. 1632 and about 15,000,000 for No. 1633.

Both columns continue to deflect slowly in the plane of the pins after having reached a good bearing. If we consider that the columns now have the equivalent of fixed ends in this plane, No. 1632 shows a double eccentricity, $2e$, of 0.50-in., while No. 1633 shows a value of 1.04-in. Both of these values are much larger than the initial deflections, unless these columns deflected improbable amounts before the zero readings were taken.

It may be noticed that the curve for E' corresponds fairly well with the observed values of the apparent coefficient of elasticity after the columns have reached good bearings, and yet no account has been taken in this curve for the eccentricity in the plane of the pins. This is as it should be if the columns are really deflecting as with fixed ends. The gauge line, which was nearly as long as the column, included parts which were concave upward, and other parts which were convex upward and thus the two effects should nearly cancel.

It may be noted here that the method used by Professor Morris, in estimating the accidental eccentricity in the plane of the pins, is based on the assumption of fixed ends from zero load. In this way one would get very large eccentricities for the above columns and correspondingly high stresses. This qualification does not affect all of his results, but Buchanan's columns Nos. 5, 8, 9, 14, 16, and 17*¹⁴ do show considerable deflection parallel to the pins at small loads, indicating poor initial bearing.

Column 6-1881 shows a large deflection parallel to the pins for small loads, while in the plane perpendicular to the pins there is shown a very small accidental eccentricity.

Columns 467-1881 and 469-1881 illustrate cases in which the initial crookedness of the column is recorded. The tests show eccentricities greatly exceeding the initial bends.

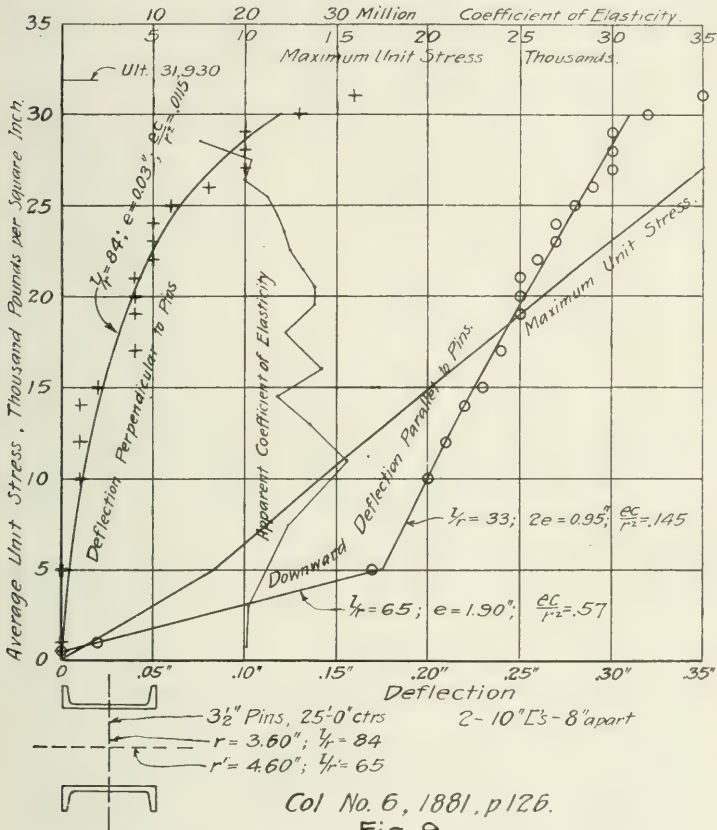
Columns 24-1881 and 466-1881 show sudden changes of eccentricity in their deflections parallel to the pins at small loads. In the first case the initial errors in the bearings may have both been on the same side of the column, and in the second case they may have been on opposite sides. This view is confirmed by the first value for the apparent coefficient of elasticity, which in the first test is very high while in the second test the first two values of this coefficient are not as high as the third. It must be ad-

*14—This deflection parallel to the pins at small loads is so characteristic that one may question if some error has not been made in the published account of Buchanan's column 17, for it shows a deflection at small loads in the plane *perpendicular* to the pins, which is most unusual and for which no explanation is evident.

mitted that the values of the coefficient of elasticity for column 466 are not satisfactory. The test itself was interrupted at the maximum load shown in the diagram for the purpose of placing additional packing under the bolster at one end.

Column 338-1884 illustrates the case of a column with flat ends, which shows eccentricity in both planes as well as faulty bearing in one plane.

Columns 1630-1883 and 1654-1883 show the peculiar phenom-



enon of a retrograde elastic deflection. The initial deflection in each case is probably due to poor bearing at one or both ends, but after reaching good bearings each column shows a smaller eccentricity opposite to the initial eccentricity. In column 1630 the deflections in both planes at large loads unite in making the apparent coefficient of elasticity to increase instead of decrease beyond the proportional limit.

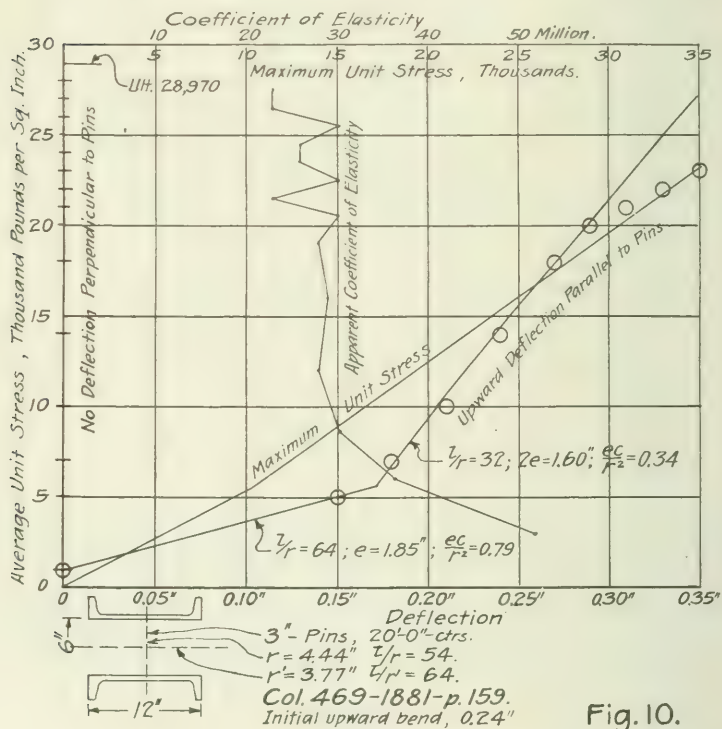
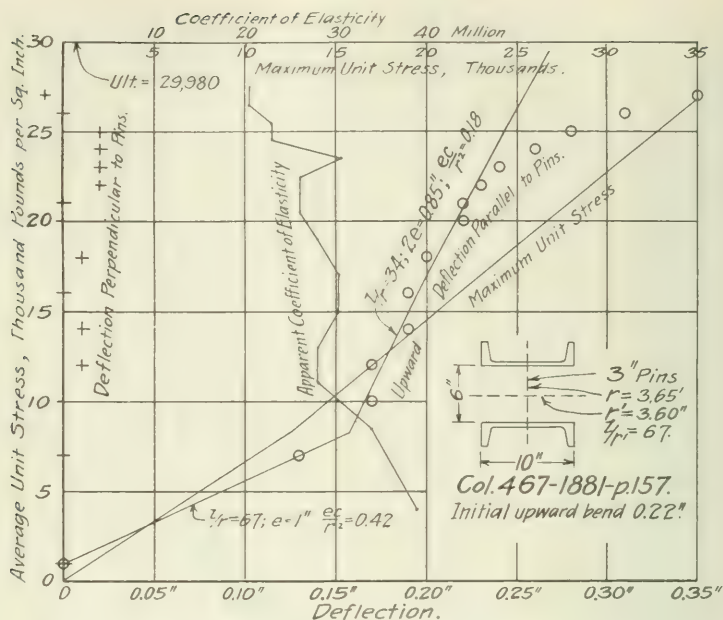
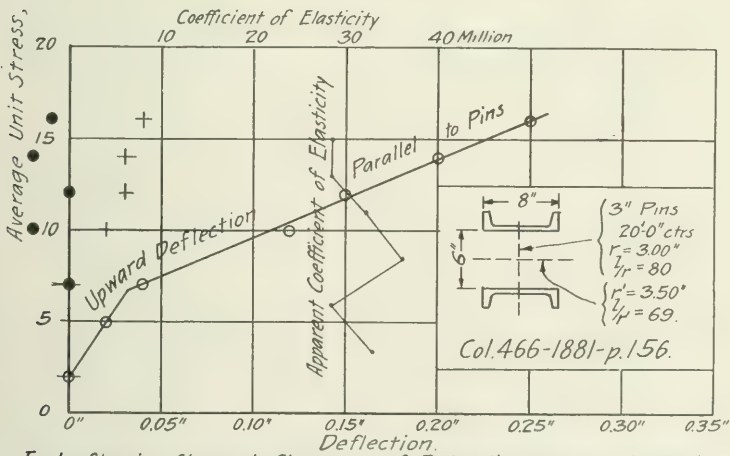
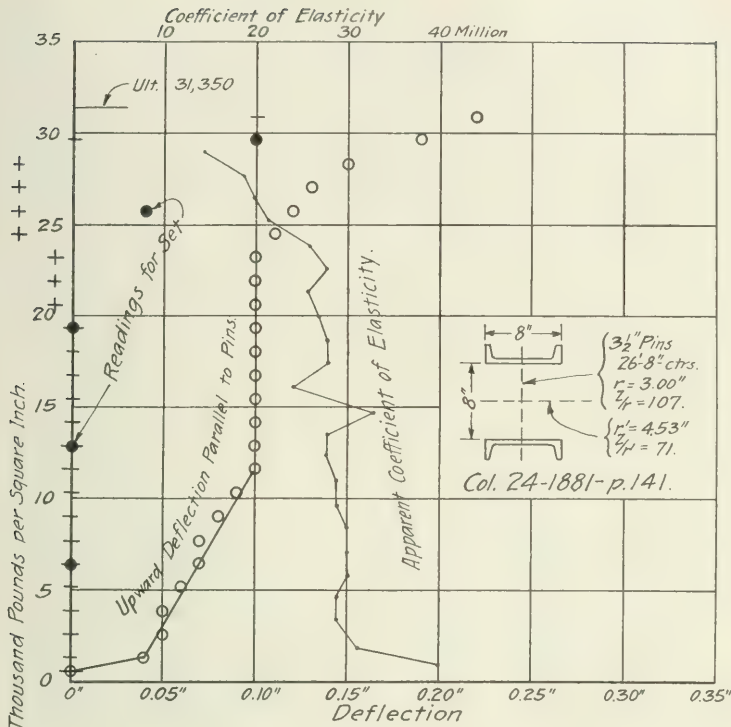


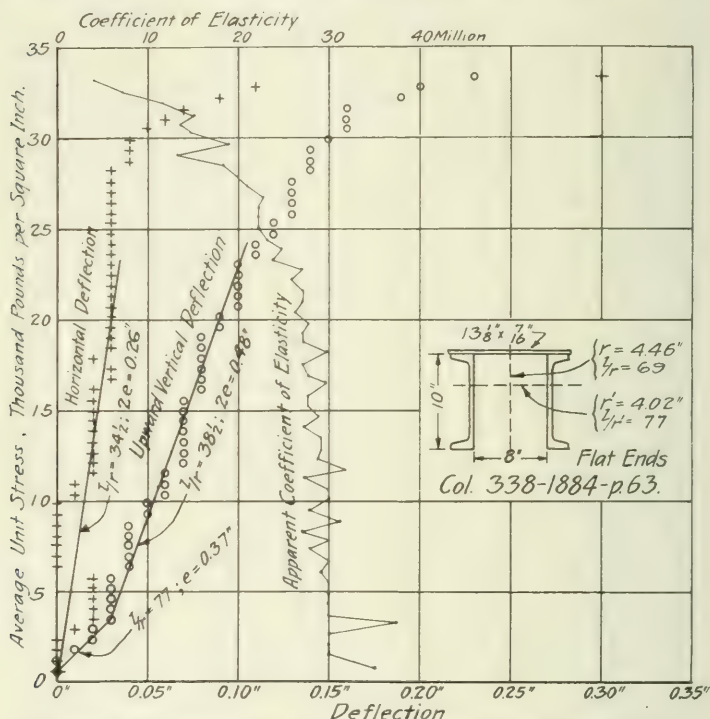
Fig. 10.



Tests Showing Change in Character of Deflection at Small Loads.

Fig. 11.

Action of Pins.—The effective eccentricity of a column in the plane perpendicular to the pins may be a function of the friction present between the pins and the pin plates. Let the radius of the pins be R and the angle of friction be ϕ . If there is a good fit between the pins and their bearings, we should expect that there would be no slipping of the pins until the effective eccentricity at the ends reaches the value $R \sin \phi$. Accordingly we might expect most centrally loaded columns, tested with pin ends, to begin to

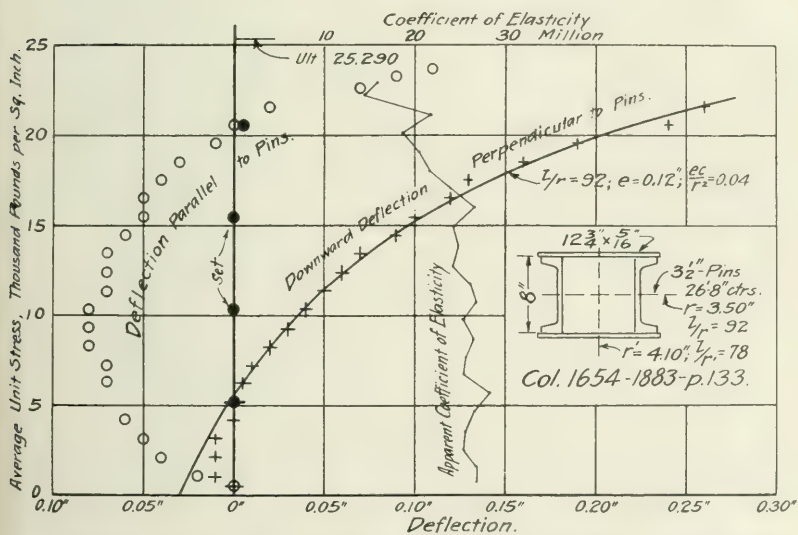
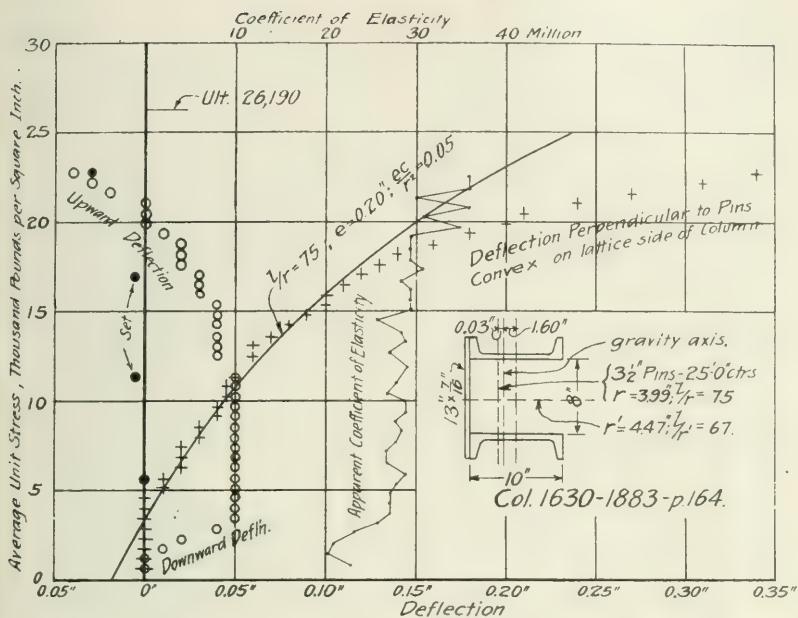


Example of Eccentricity in Column Tested with Flat Ends.

Fig.12.

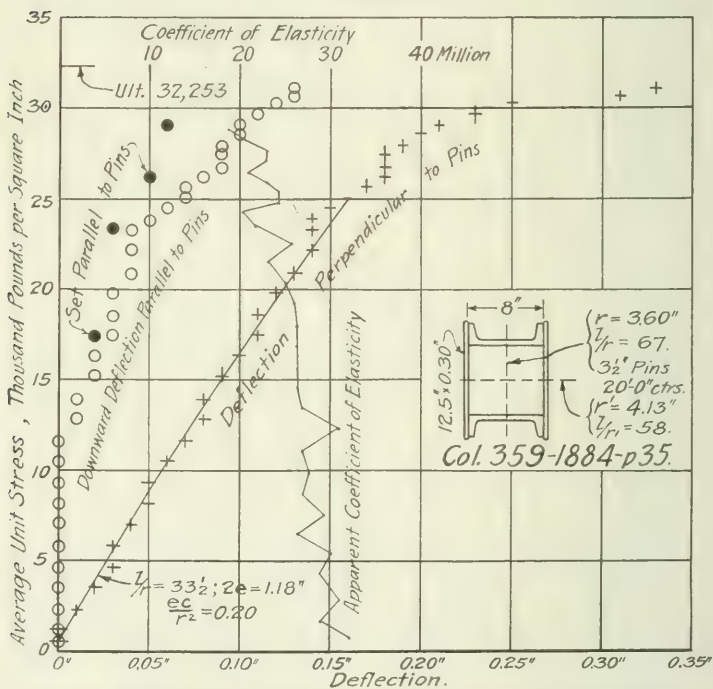
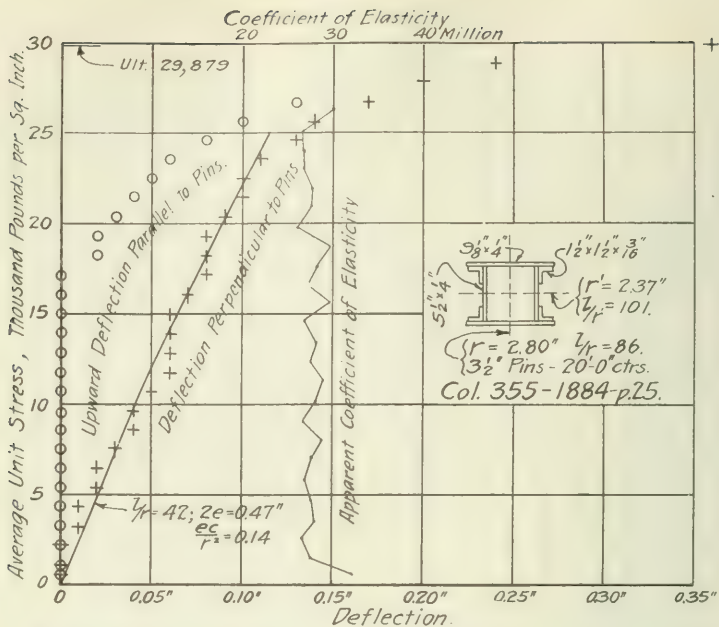
deflect as columns with fixed ends. We might also expect that eccentrically-loaded columns would deflect with an effective eccentricity which is smaller than the intended eccentricity by this friction arm, $R \sin \phi$.

In many tests, such as those of columns 1630-1883 and 1654-1883, it is a fact that the deflection perpendicular to the pins does not begin until the load on the column has reached a considerable value, and thereafter it follows a curve which in many cases does not pass through the zero reading. A few tests have been found,



Tests in which the deflection parallel to the pins changes direction & yet remains practically all elastic below 20,000 lbs. per sq. in.

Fig. 13.



Columns with Pins Deflecting as Columns with Fixed Ends.
Fig. 14.

in which the whole elastic deflection perpendicular to the pins indicates that the column deflected as if it had fixed ends, i. e., with a slenderness ratio only half its real value. Two such cases are columns 355-1884 and 359-1884. If we accept this interpretation, we find that the angle of friction was not less than 9° for the first test, and not less than 20° for the second.

If we now refer to columns 350, 1632, and 1633, which were tested with intended eccentricities and whose accidental eccentricities were only 0.06-in., 0.12-in., and 0.15-in. respectively, and if we assume that these represent the whole of the friction effect, we find the angle of friction for these cases to be 2° , 4° , and 5° respectively. From this point of view, therefore, the accidental eccentricities found for these three columns are in the right direction but are too small.*¹⁵

Rolling.—Let us now consider a pin bearing of a somewhat ideal character—not without friction but of such ample proportions that the pin does not bed itself into its seat but rests upon an elastic cylindrical surface, as shown in Fig. 15.

Let the radius of the pins be denoted by R , and that of the pin holes by $R+m$; thus, according to ordinary specifications, the value of m is 0.01 in. for pins whose diameters are 5 in. or less, and 1/64 in. for larger pins. For zero load on the column, let the points of contact between the pins and their pin holes be on a line connecting the pin centers, i. e., at A in Fig. 15.

When the load is placed upon the pins, the column deflects and its ends rotate through the small angle, α , whose value is given in Equation 10. The small rotation of the pin hole about the fixed pin causes the point of contact to move from A to F , Fig. 15, thus revolving through an angle, β , about the center of the pin. The load is now transmitted from the pin to the pin hole at F , so that the eccentricity has been decreased by an amount e' such that $e' = R \sin \beta$. Since the angle α is very small, we may take its

value as, $\alpha = \frac{m \sin \beta}{R}$. Now, in place of e in Equation 10, we must use $(e-e')$, hence we get

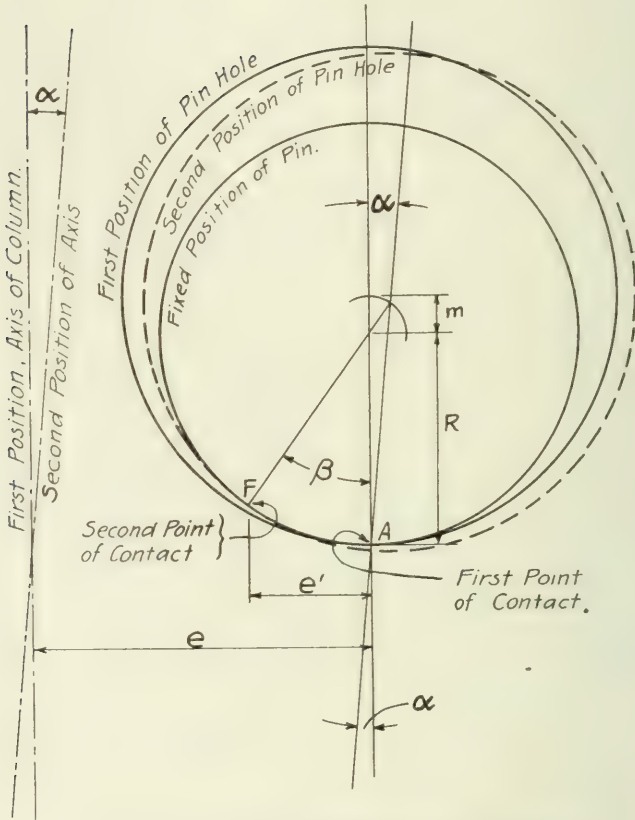
$$\alpha = \frac{m e'}{R^2} = (e-e') k \tan \theta, \text{ or}$$

*¹⁵—For these columns the ratios of the cross section to the bearing area are:

350-1884.....	1.39
1632-1883.....	1.89
1633-1883.....	1.90
355-1884.....	1.07
359-1884.....	1.86

The average unit stress multiplied by this ratio gives the unit stress in bearing under the pins.

$$\frac{c'}{c} = \frac{1}{1 + \frac{m}{R^2 k \tan \theta}} \dots \text{Eq. 14.}$$



As the column bends the point of contact moves toward the axis.

Fig 15.

In the above we have assumed that the pins are so fixed in their bolsters that they cannot rotate. If we now assume that there is the same play in their bolsters as in their pin plates, Equation 14 becomes,

$$\frac{e'}{e} = \frac{1}{1 + \frac{2m}{R^2 k \cdot \tan \theta}} \dots \dots \dots \text{Eq. 14'}$$

Rolling always decreases the initial eccentricity. If there is a close fit between the pins and their pin holes, the decrease in eccentricity is very considerable especially for slender columns under large loads. As an illustration we may take a column whose radius of gyration is $6\frac{1}{4}$ in. and whose pins are 5 in. in diameter. Let the diameter of the pin holes be 5.02 in. both in the pin plates and in the supporting bolsters. For such a column of various lengths and under different loads, the ratios of e' to e would have the values shown in the following table:

RATIOS OF e' TO e .

Average Unit Stress.	Slenderness Ratio $l \div r$						
	50	60	70	80	90	100	110
5,000	0.18	0.22	0.25	0.28	0.31	0.34	0.37
10,000	0.31	0.36	0.40	0.45	0.49	0.54	0.59
15,000	0.41	0.47	0.53	0.58	0.64	0.69	0.76
20,000	0.49	0.56	0.62	0.68	0.75	0.82	0.89

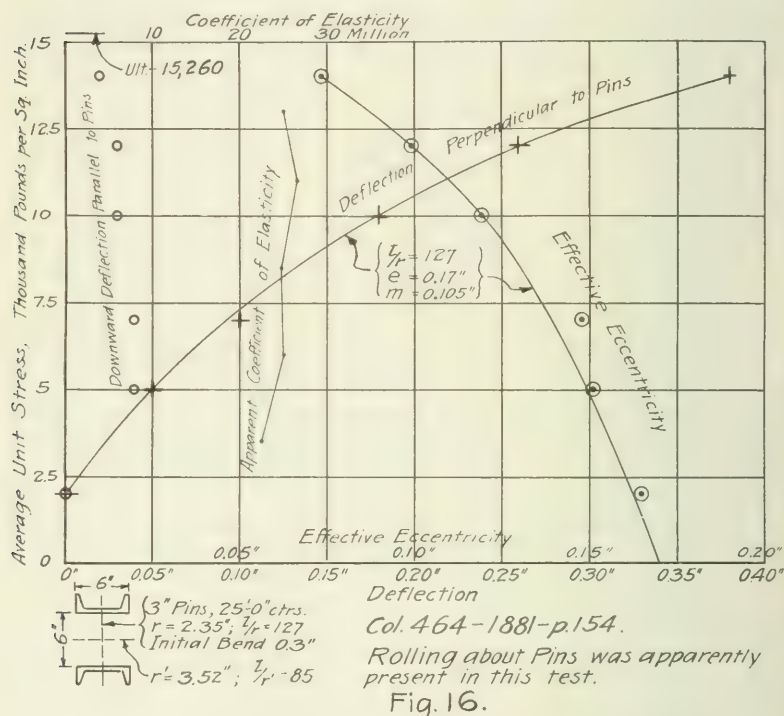
For the conditions which we have assumed the value of e' can never exceed the friction arm, $R \sin \phi$. It may be interesting to note, however, that the initial point of contact may not be on a line connecting the centers of the pins; it may be at either side of that line at a distance not to exceed the friction arm $R \sin \phi$. In such a case the formula given for e' would need modification, and the greatest possible value of e' would be $2 R \sin \phi$. Pin friction is thus seen to be a possible source of initial eccentricity, which, however, will become smaller with increase of load.

The deflections given in the test of column 464-1881 are in excellent agreement with the above discussion of rolling. In this case the value of m is taken as 0.105 in. This value seems large, but it is to be remembered that m is the amount by which the sum of the radii of pin holes, both of the pin plates and of the bolster, exceeded the diameter of the pin. In the diagram of this test a curve is shown for the effective eccentricity ($e - e'$), calculated from Equation 14; but the points plotted for the effective eccentricity have been calculated from the observed deflections by means of Equation 3.

The deflections of column 22-1881 for loads beyond 5,000 lb. per sq. in. agree well with a curve drawn for a slenderness ratio of 77, whereas the actual value of this ratio was 120. Practically the same curve may be obtained if we assume an initial eccentricity

of 0.113 in., a slenderness ratio of 120, and rolling about the pins for which the value of m is 0.055 in. It is interesting to note that the ultimate strength of this column was 24,850 lb. per sq. in., in spite of the fact that its initial eccentricity was evidently considerable and that Euler's formula gives about 19,200 lb. per sq. in., as the ultimate strength of such a column when the load is axial. This may be explained on the assumption of rolling by noting that, when the initial eccentricity is not too large, the effective eccentricity may not only disappear through rolling, but it may become negative.

If we try to account for the accidental eccentricities of columns



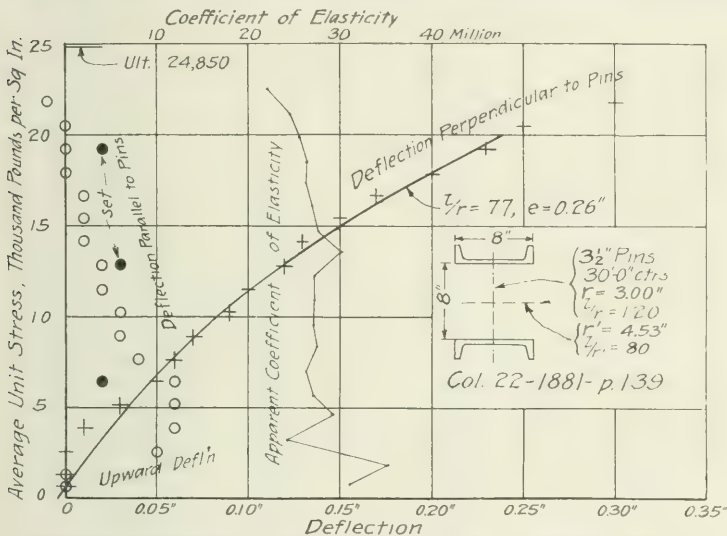
1632-1883 and 1633-1883 on the assumption of rolling, we find the value of m to be about 0.15-in. and 0.12-in. respectively, and the curves obtained do not fit the observed deflections as well as those shown. In the case of column 350-1884, the required value of m would be about 0.44-in., which is so large as to make the hypothesis of rolling improbable, except that it may possibly explain the small values for the observed deflections for loads below 6,000 lb. per sq. in.

Oblique Loads.—Columns in structures are subject to some

sources of accidental eccentricity not likely to be met in laboratory tests. The columns of an elevated railway structure may be firmly secured to their footings and to their heavy girders, and yet have an eccentricity due, first, to inclination to the vertical, second, to horizontal shear caused by wind or by centrifugal force, and third, to bending moment introduced by the deflection of the girders when under load.

LOCAL ECCENTRICITY.

The eccentricity hitherto discussed relates to the column as a whole. Professors Talbot and Moore,*¹⁶ have pointed out that, in certain cases, large stresses may arise through the local eccentricity of the load carried, not by the whole column, but by a portion of it, e. g. by one channel in a latticed column. In their tests "indications



Rolling about the Pins apparently has caused this column to deflect as if its slenderness ratio were much smaller than its real value

Fig. 17.

of a fiber stress of from 40% to 50% in excess of the average stress were not unusual."

In explanation of this we may note that it is only the stiffness of the column ribs that prevents them from assuming an undulating form somewhat as shown in Fig. 18. A column may approach this form in certain parts due to local crookedness. If its departure from a straight line is e , due both to an initial bend and to deflection under load, the maximum stress will exceed the aver-

*16—University of Illinois Engineering Experiment Station, Bulletin No. 44, p. 54.

age stress by the ratio $\frac{ed}{r^2}$, in which d is the distance of the most

stressed fiber from the gravity axis of the single rib, and r is the radius of gyration of the single rib. We may call this ratio the "excess ratio." It differs from the eccentric ratio in that the eccentricity involved includes deflection. If the radius of gyration is small, the

value of this excess ratio, $\frac{ed}{r^2}$, may be considerable even for a small

value of the local eccentricity. Thus, in two cases cited by Talbot and Moore eccentricities of only 0.045 in. and 0.057 in. respectively were needed to make the maximum stress 50% greater than the average stress.

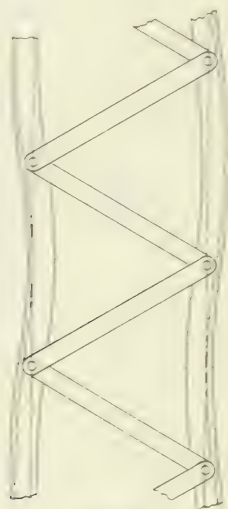


Fig. 18.

In specifications it is customary to require that the portion of a column rib between successive connections of lattice bars shall have a slenderness ratio not larger than that of the whole column. While this may prevent the rib from buckling, it does not insure a uniform distribution of stress over the section of the rib. The general eccentricity of the column throws a large proportion of the load on one rib and the effect of the local eccentricity is to still further increase the stress in certain parts of that rib. The local eccentricity may thus play as important a part in the failure of the column as the general eccentricity, even though its effect is not directly shown in buckling. It has been repeatedly found that the proportional limit of built up columns is remarkably low. While

the stresses introduced in punching and riveting doubtless have something to do with this result, it is likely that this local eccentricity is an important factor. Although a column does not fail, as a rule, at a load that is near its proportional limit, such a test is generally completed in an hour or two, and it is not at all certain that the ultimate loads would greatly exceed the proportional limits if such loads remained in place for a long time.

RATIONAL DESIGN FOR COLUMNS.

If one wishes to estimate in a manner as nearly rational as possible, the load suitable for a given column, how shall he proceed? The following program is tentatively suggested:

1. The *stress due to fabrication* should be estimated and subtracted from the tensile yield point of the material giving the *maximum elastic stress of the column*.

2. The excess ratio $\frac{ed}{r^2}$, due to local eccentricity in one rib of the column, should be estimated. The maximum elastic stress of the column divided by $\left(1 + \frac{ed}{r^2}\right)$ will give a *dangerous maximum unit stress*. It will be appropriate for the profession to adopt standard dangerous maximum stresses for the various types of columns in general use.

3. For each of the two planes of the column an eccentricity should be selected which, in the opinion of the designer, will surely not be exceeded in the column. Using these eccentricities in Equation 2, or its equivalent, a *dangerous average stress*, p_0 , may be found such that the maximum unit stress, p , given by this equation equals the dangerous maximum unit stress defined in item 2.

4. The *safe average stress* may be found by dividing the dangerous average stress by the factor of safety.

Notes on Program.—As stress due to fabrication, allowance may be made for metal cut out at rivet holes and for stresses introduced in straightening, punching, and riveting. In making this estimate, proper regard should be had for the fact that after over-strain steel tends to recover its former properties with the lapse of time.

While it is possible to estimate the dangerous maximum stress for a latticed column whose ribs are composed of channels or of plates and angles, there are many types of columns for which this cannot be done with any degree of certainty. In such cases the question is intimately connected with the subject of wrinkling which has been studied by Prof. W. E. Lilly.*¹⁷ On account of our pres-

*¹⁷—*Engineering*, Jan. 10, 1908.

	Slenderness Ratio									
	50	60	70	80	90	100	110	120	130	140
5	1.05	1.08	1.11	1.15	1.20	1.25	1.32	1.40	1.50	1.62
6	1.07	1.10	1.14	1.18	1.24	1.31	1.40	1.51	1.63	1.82
7	1.08	1.11	1.16	1.22	1.29	1.38	1.50	1.64	1.83	2.08
8	1.09	1.14	1.19	1.26	1.35	1.46	1.60	1.79	2.05	2.41
9	1.10	1.15	1.22	1.30	1.41	1.54	1.72	1.97	2.32	2.85
10	1.12	1.17	1.25	1.34	1.47	1.63	1.86	2.18	2.65	3.46
11	1.13	1.19	1.28	1.39	1.54	1.74	2.02	2.44	3.12	4.38
12	1.14	1.21	1.31	1.43	1.61	1.85	2.22	2.56	3.74	5.88
13	1.15	1.23	1.34	1.49	1.69	1.98	2.42	3.16	4.63	8.69
14	1.17	1.25	1.37	1.54	1.77	2.12	2.68	3.69	6.02	16.4
15	1.18	1.28	1.41	1.60	1.87	2.29	2.99	4.40	8.46	172
16	1.19	1.30	1.45	1.66	1.97	2.47	3.38	5.43	14.4	
17	1.21	1.32	1.49	1.72	2.09	2.69	3.87	7.04	39.0	
18	1.22	1.35	1.53	1.79	2.21	2.95	4.51	9.86		
19	1.24	1.37	1.57	1.87	2.36	3.25	5.39	16.4		
20	1.25	1.40	1.62	1.95	2.51	3.62	6.65	47.4		
21	1.27	1.43	1.66	2.04	2.69	4.07	8.63			
22	1.28	1.45	1.71	2.13	2.90	4.65	12.3			
23	1.30	1.48	1.77	2.24	3.13	5.40	20.9			
24	1.31	1.51	1.82	2.35	3.40	6.41	65.9			
25	1.33	1.54	1.88	2.47	3.73	7.87				
26	1.35	1.57	1.94	2.61	4.10	10.1				
27	1.37	1.61	2.00	2.76	4.57	13.8				
28	1.38	1.64	2.08	2.93	5.15	22.9				
29	1.40	1.68	2.15	3.11	5.84	57.3				
30	1.42	1.72	2.23	3.32	6.79					
31	1.44	1.75	2.32	3.56	8.04					
32	1.46	1.79	2.41	3.83	9.86					
33	1.48	1.84	2.51	4.14	12.7					
34	1.50	1.88	2.61	4.50	17.3					
35	1.52	1.92	2.73	4.93	28.7					
36	1.54	1.97	2.83	5.43	68.7					
37	1.56	2.02	2.98	6.02						
38	1.59	2.07	3.13	6.80						
39	1.61	2.13	3.29	7.73						
40	1.63	2.18	3.46	9.07						
41	1.66	2.24	3.66	10.8						
42	1.68	2.31	3.87	13.3						
43	1.71	2.37	4.11	17.2						
44	1.74	2.44	4.38	24.6						
45	1.76	2.51	4.68	43.0						
46	1.79	2.59	5.03	172.						
47	1.82	2.67	5.42							
48	1.85	2.76	5.88							
49	1.88	2.85	6.42							
50	1.91	2.95	7.06							

Table of
Eulerian Secants
 $\sec \frac{1}{2r} \sqrt{\frac{P_0}{E}}$

$E = 30,000,000$

Multipliers of $\frac{ec}{r^2}$
in Expression for
Maximum Stress.

Fig. 19.

ent lack of knowledge in this respect, it would be appropriate for this subject to be thoroughly discussed by engineers, and for certain values to be adopted as dangerous maximum stresses to be used in connection with various types of columns.

The table of Eulerian secants given as Fig. 19 may assist in the selection of a dangerous average stress. This secant gives the ratio of the final eccentricity ($e + \Delta$), to the initial eccentricity, e ; thus for an average stress of 24,000 lb. per sq. in. one sees from the table that deflection increases the eccentricity 51% if the slenderness ratio is 60; but 240% if the slenderness ratio is 90.

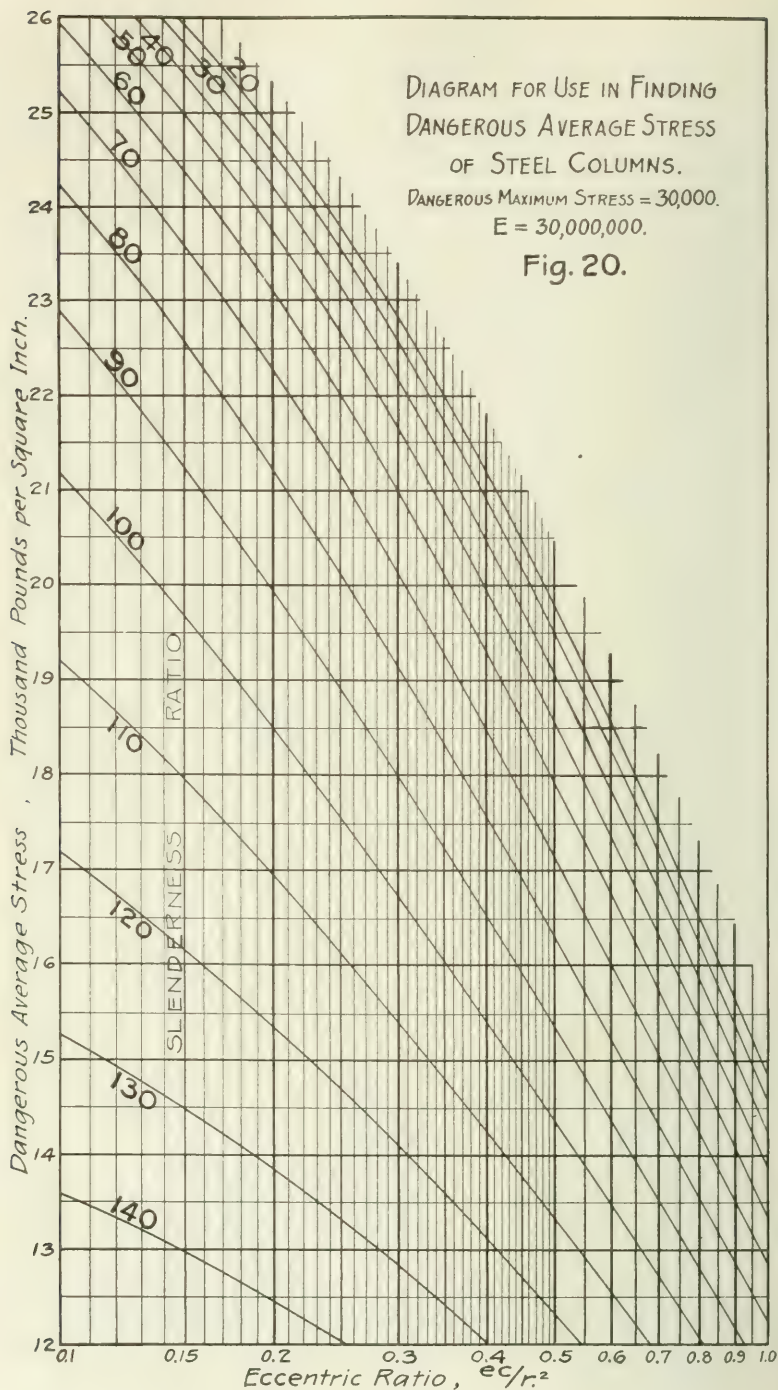
As an illustration of the proposed method of estimating the dangerous average stress, let us suppose that the dangerous maximum stress has already been determined as 30,000 lb. per sq. in. Let the length of the column be 190 in. If $r_z = 3.8$ in., $l/r_z = 50$. Let $e_z = 0.75$ in., and $z = 5$ in., $e_z z/r_z^2 = 0.26$. If $r_y = 3.1$ in., $l/r_y = 61$. Let $e_y = 0.62$ in., and $y = 5$ in., $e_y y/r_y^2 = 0.32$. The deflection may be depended upon to increase the excess ratios by about 30% as a first estimate, so that the total excess ratio will be 1.30 ($0.26 + 0.32$) or 0.75, and our first estimate of the dangerous average stress will be $30,000 \div 1.75$ or 17,100 lb. per sq. in. If we check this we find that such an average stress will produce a maximum stress of 29,800 lb. per sq. in. in place of 30,000. Thus we see that 17,200 corresponds more nearly to our assumed conditions than 17,100.

When there is only one eccentricity and only one slenderness ratio, and when the dangerous maximum stress is 30,000 lb. per sq. in., the diagram given as Fig. 20 may be used to give an immediate solution for the dangerous average stress. In using it one simply locates a point which corresponds to the given excess ratio and the given slenderness ratio, and then reads its elevation on the vertical scale as the appropriate dangerous average stress.

Two slenderness ratios and two eccentric ratios may be reduced to a single equivalent set by the approximate method of taking values which are the mean of the slenderness ratios and the sum of the eccentric ratios respectively. Thus, in the illustration used above, the equivalent slenderness ratio is $55\frac{1}{2}$ and the equivalent eccentric ratio is 0.58. Using these values in the diagram, we reach the value 17,200 lb. per sq. in. directly.

This diagram is good for only the one dangerous maximum stress, 30,000 lb. per sq. in., but similar diagrams can be easily made for other stresses, each one being appropriate for some particular type of column.

Against the above program, it may be objected that the modern method of design is to use prescribed allowable stresses or maximum working stresses instead of given fractions of dan-



gerous average stresses. Would it do as well to use the load which will produce a maximum stress of 15,000 lb. per sq. in. instead of using half the load which will give 30,000 lb. per sq. in. maximum stress? The answer is that it would not, although for most columns it is not a matter of great importance. The maximum stress curve is not a straight line, as may be seen in Figs. 3, 7, and 8. The method proposed in the program gives the full factor of safety used, whereas the other method would give a variable factor of safety but always somewhat smaller than it appeared to be. Thus the use of steel having a higher yield point will increase the safe load for a short column much more than for a long column.*¹⁸ Such a result might not be foreseen if one worked with allowable stresses, but it comes as a matter of course in the use of the method proposed.

LATTICE BARS.

The forces which act upon lattice bars may be divided into three classes: first, those introduced in the fabrication of the column; second, those due to transverse shear caused by local bends in the column; and third, those due to transverse shear caused by general inclination of the column.

The forces of the last two classes will cause elongations or shortenings of the lattice bars when the column load is varied, and may be investigated by means of extensometer measurements upon columns already built. Those of the first class will not become evident in such tests, but may be investigated by laying off gauge lines on the bars and taking extensometer readings on them, both before they are riveted to the columns, and after that process.

Let us call the transverse shear, which would cause the first force, S_1 . If experiments have been made to determine the value of this shear, S_1 , they are not known to the author.

The presence of the second class of forces has been amply shown in the tests*¹⁹ of Professors Talbot and Moore. The case is illustrated in Fig. 21, where the column, in a length, s , is shown as bent or sheared a distance, δ , out of a straight line. If we let S_2 represent the transverse shear which the lattice bars in this section must carry, we have

$$S_2 = A p_0 \frac{\delta}{s} \dots \dots \dots \text{Eq. 15.}$$

A very small amount of this shear may be carried by the ribs themselves due to their own stiffness, which is neglected in the above

*¹⁸—Waddell found that struts 10 ft. long, made of nickel steel, were 75% stronger than similar struts made of carbon steel, but for struts that were 30 ft. long, the advantage of nickel steel was only 47%.—See *Trans. Am. Soc. C. E.*, Vol. 63-1909.

*¹⁹—*Bulletin 44, University of Illinois Engineering Experiment Station.*
June, 1913

expression. In the tests referred to, the maximum value of the transverse shear, indicated by extensometer measurements on lattice bars, was about 3% of the total load on the column, and it is fairly evident, from the distribution of these stresses among the successive lattice bars, that they were due very largely to local bends in the columns.

The transverse shear, S_3 , which arises from a general inclination of an eccentrically-loaded column, may be treated as two separate cases, first, in which the eccentricities, e , at the two ends of the column and parallel to the lattice, are on the same side of the axis, and, second, in which they are on opposite sides of the

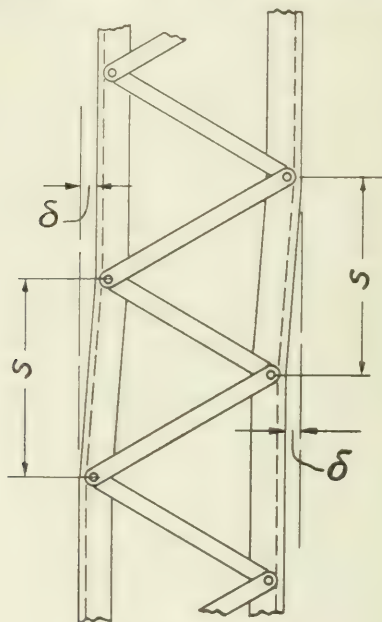


Fig. 21.

axis. In the first case the maximum shear will come at the ends of the column, and will be

$$S_3 = A p_0 \frac{e}{l} 2 \theta \tan \theta \dots \dots \dots \text{Eq. 16,}$$

while in the second case the shear will be largest at the middle of the column, and its expression is

$$S_3 = A p_0 \frac{e}{l} 2 \theta \csc \theta \dots \dots \dots \text{Eq. 17.}$$

The tables shown in Fig. 22 give values of the trigonometric multipliers shown at the right of Equations 16 and 17. For small loads the shear found in Equation 17 is larger than that of Equation 16; the controlling values are found below the dotted line in the upper table, and above the dotted line in the lower table.

If the shear is carried by two sets of single latticing, whose

	Slenderness Ratio										
	50	60	70	80	90	100	110	120	130	140	
Average Unit Stress, P_0	5	0.22	0.32	0.44	0.59	0.76	0.97	1.22	1.51	1.87	2.28
	10	0.45	0.67	0.95	1.31	1.77	2.36	3.16	4.25	5.79	8.15
	15	0.70	1.06	1.56	2.23	3.18	4.60	6.93	11.5	137.	568.
	20	0.98	1.51	2.29	3.46	5.36	8.98	18.7	146.		
	25	1.27	2.04	3.22	5.22	9.32	22.5				
	30	1.60	2.64	4.42	8.01	19.2					
	35	1.96	3.37	6.07	13.2	91.					
	40	2.36	4.25	8.52	26.4						
	45	2.81	5.12	12.4	144.						
	50	3.33	6.80	20.0							
Table of $\frac{L}{F\sqrt{E}} \cdot \tan \frac{L}{2r}\sqrt{\frac{P_0}{E}}$ Controls below dotted line.											

	Slenderness Ratio										
	50	60	70	80	90	100	110	120	130	140	
Average Unit Stress, P_0	5	2.04	2.05	2.07	2.09	2.12	2.15	2.18	2.22	2.25	2.30
	10	2.07	2.10	2.14	2.19	2.24	2.31	2.38	2.46	2.56	2.67
	15	2.11	2.16	2.22	2.29	2.38	2.48	2.61	2.76	2.93	3.13
	20	2.15	2.22	2.30	2.40	2.53	2.69	2.87	3.10		
	25	2.18	2.27	2.39	2.52	2.70	2.91				
	30	2.22	2.33	2.47	2.65	2.88					
	35	2.27	2.40	2.57	2.79	3.08					
	40	2.31	2.46	2.67	2.94						
	45	2.35	2.53	2.77	3.10						
	50	2.39	2.60	2.89							
Table of $\frac{L}{F\sqrt{E}} \cdot \csc \frac{L}{2r}\sqrt{\frac{P_0}{E}}$ Controls above dotted line.											

Multipliers of $Ap_0\frac{L}{r}$, for Use in Finding the Maximum Shear.
Fig. 22.

bars make the angle, λ , with the axis of the column, the load on each bar may be taken as

$$P = \frac{1}{2} (S_1 + S_2 + S_3) \csc \lambda \dots \dots \dots \text{Eq. 18.}$$

In this the expressions S_2 and S_3 depend upon p_0 , the average stress over the column section. It will be well to make this p_0 the dangerous stress instead of the safe stress. In that case the lattice

bar is designed for its load in just the same way as the column section, except that the factor of safety has already been introduced by taking p_0 in Equation 18 as the dangerous average stress. This device introduces the same factor of safety into the lattice bars as is used for the column section.

In this connection it should be remembered that the lattice bar is likely to receive a very eccentric load. By ordinary specifications, lattice bars may have a slenderness ratio of about 140. From a very liberal point of view, we might assume them to have fixed ends with a double eccentricity equal to half the thickness of the bars. This would make the excess ratio 150% without any allowance for deflection. For "under" bars Talbot and Moore found a measured excess ratio of about 55%^{*20} while for six "over" bars its average value was 247%, and one excess ratio reached 450%. These measurements were made while the bars were under such light loads that their deflections would not be important. It is to be hoped that the profession will soon adopt some form of lattice bar better adapted than the flat bar to carry eccentric compressive loads.

The above discussion of lattice bars is appropriate to specially large columns, or to those whose maximum shear will come when under load. For most columns of ordinary proportions it is probable that their maximum shears come while they are being handled in the shop or in transportation or in erection, and to provide for such loads the bars should not be made smaller than has been found good practice.^{*21}

CONCLUSION.

The actual maximum stress present in a column under load is a function of the imperfections of the column, both with respect to its manufacture and with respect to the manner of loading. It is believed that the engineering profession should face these imperfections squarely, that information regarding these imperfections should be sought diligently, and that columns should be designed with some reference to the maximum values of such imperfections—not of columns as a whole but either of individual columns or of types of columns.

*20—Bulletin 44, Table 13.

*21—The provision that the latticing of compression members shall be proportioned to resist the shear corresponding to the allowance for flexure $\frac{1}{r}$ for uniform load provided in the column formula by the term $70\frac{1}{r}$

apparently means that this shear shall be taken as $280\frac{Ar}{c}$ lb. This formula assumes that the whole of the eccentricity is in the plane parallel to the latticing and is likely to require, for slender columns, lattice bars that are too heavy in proportion to those required for stouter columns.

DISCUSSION.

WRITTEN DISCUSSION BY MESSRS. O. H. BASQUIN, H. F. MOORE,
J. H. GRIFFITH, R. S. CHEW, HORACE R. THAYER, A. W.
CARPENTER, LEWIS E. MOORE, EDWARD GODFREY,
W. E. LILLY AND F. O. DUFOUR, PRE-
SENTED APRIL 14, 1913.

Mr. Basquin:

In his presentation of the paper, December 9th, the author made the following variations from the copy as printed:—

It was intended that Equation 5 should appear in the following form:

$$E' = \frac{E}{1 + \frac{(c_z + \Delta_z)(g_z + \Delta_z)}{r_z^2}} \dots \dots \dots \text{Eq. 5.}$$

and this form is found in figures 3, 7 and 8.

In figures 7, 8, 9 and 10 the columns show, at small loads, anomalous values for the apparent coefficient elasticity, which peculiarity is due to large initial eccentricity parallel to the pins caused by defective bearings. If we let e_y be the eccentricity perpendicular to the pins and e_z be that parallel to them, we may calculate the following values for the apparent coefficient of elasticity, E' :—

Fig.	Col.	e_y inches	e_z inches	E' lb. per sq. in.
7	1632	1.50	—1.87	38,000,000
8	1633	1.47	2.50	17,000,000
9	6	0	1.90	20,000,000
10	467	0	—1.00	40,000,000
10	469	0	—1.60	49,000,000

Reference to the diagrams will show that these values for E' agree with the values derived from observation, as well as could be expected.

While the tests made by Buchanan were practically confined to top chords of bridges they are thought to be particularly reliable in that field. The test pieces were not specially designed and built for test but were duplicates of members placed in bridges. The purpose was to detect faults of the columns either in design or in fabrication and Buchanan says that "the earlier tests demonstrated . . . that a compression member having one or two sides

lattice is likely to fail under a smaller load than indicated by any accepted formula." It is believed that most columns tested are adjusted to their bearings in the testing machine with greater care than is used when erecting similar columns in fabricated structures. That these columns were not so adjusted is indicated by the large eccentric ratios found for them parallel to the pins. It is believed, further, that the machines in which most columns are tested are much more heavily built than the structures in which corresponding columns are used. The machine used in Buchanan's tests was originally built for a maximum load of 500,000 lb.; fourteen of these fifteen columns carried loads in excess of this figure and two columns failed at loads greater than 1,000,000 lb. While the frame of the machine had been strengthened, it was probably not so stiff as other machines in comparison with the loads carried.

SUMMARY OF PAPER.

About six years ago an editorial in *Engineering News* begins with the remark that "there is no better device for 'whipping the devil round the stump' than the invention or promotion of a new column formula." I have sought to avoid such a charge.

I have suggested that many column tests may be unreliable because made with too great care, on machines too rigidly built and completed in too short a time.

I have tried to show:—

1. That columns tested under intended eccentric loads deflect in accordance with the simple theory—which corresponds with the ordinary theory of bending used for beams.
2. That a column load supposed to be central may have a considerable eccentricity.
3. That the peculiarities of many column tests may be satisfactorily explained by the assumption of such eccentricity.
4. That eccentricity may be introduced in a number of different ways and hence its maximum value will not be likely to be found in a few tests.
5. That, by consideration of the various sources of eccentricity, it should be possible to set a reasonable limit to such eccentricity for any particular type of column.
6. That columns may be designed by a method that is largely rational.
7. That, while the empirical method may be satisfactory for columns of ordinary size and proportion, a rational method seems essential in the design of very large compression members or those of unusual form.

H. F. Moore (University of Illinois): Professor Basquin's paper is a contribution of no small value to the widespread discussion of columns. To the writer it seems especially valuable in

its recognition of the marked effect which conditions of fabrication and erection of columns exert on their strength. In discussing this paper comment on certain phenomena of column action from the viewpoint of the testing engineer may not be amiss.

The low values of modulus of elasticity computed by Professor Basquin from the data of various tests of columns may be explained, in part at least, by the fact that as regards bending action the cross-section of a built-up column does not act as a perfect unit—does not preserve its integrity. Rivets slip under low stresses*²², lacing bars bend, and other local disturbances cause the fiber stresses actually developed as a result of bending action to be higher than the values computed on the basis of perfect integrity of action of cross-section. The ratio of computed to actual fiber

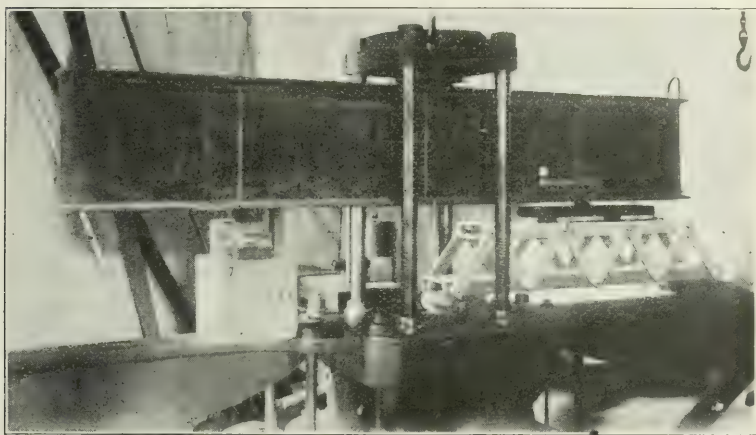


Fig. 23.

stress may be spoken of as the "flexural efficiency" of the cross-section of a built-up column. A series of tests to determine this flexural efficiency for sections made up of channels fastened together with different systems of lacing was recently made at the Laboratory of Applied Mechanics of the University of Illinois. The method of making the tests is shown in Fig. 23. Short column sections (all of the same length), were tested as beams with flexure in a plane parallel to the plane of the lacing. Assuming integrity of action of cross-section, the extreme fiber stresses in a test beam were calculated for various loads, and the actual fiber deformations developed under these loads was measured by means of a strain gauge, and the actual fiber stresses determined from the observed

* 22. Engineering Experiment Station, University of Illinois, Bulletin 49, p. 47. Iron and Steel Institute, Carnegie Scholarship Memoirs, Vol. 1 (1909), pp. 60-95.

elongations and compressions indicated by the strain gauge. In Fig. 24 is shown the variation of flexural efficiency with computed fiber stress for various column sections. In a column of usual

length in structures ($\frac{l}{r} = 50$ to 75), the compressive stress is

the principal stress in the column and the flexural stress is not very high; so in comparing the flexural efficiencies of different column sections the efficiencies under low flexural stresses are most significant. The superiority of the double-laced section with rivets at the crossing of the bars is evident; the efficiency of this section

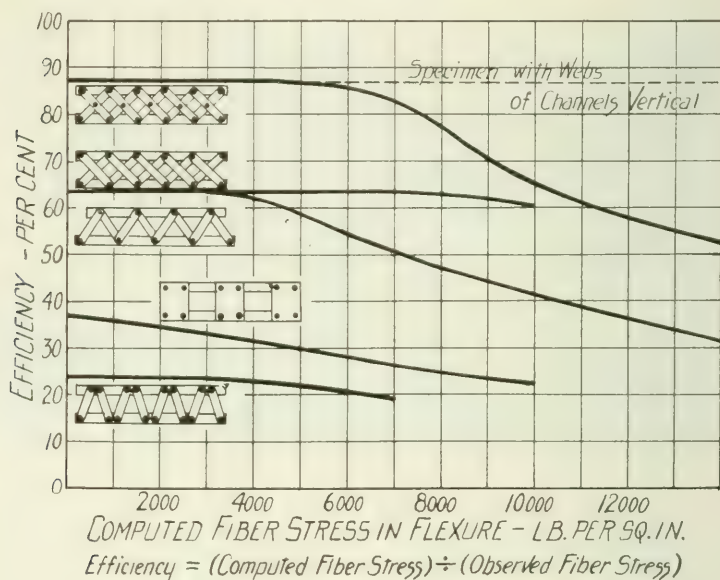


Fig. 24.

at low stress proved to be the same as the efficiency of a pair of channels tested in flexure in a plane parallel to the plane of their webs. The low efficiency of channels connected by means of batten plates is noteworthy, as is the very low efficiency of two channels connected by non-overlapping bars with only one rivet for each end of a bar. In each test piece approximately the same weight of lacing material was used, and all tests were in duplicate. Each test piece was loaded symmetrically at two points of the span, and the spans were the same for all test pieces. It should be noted that this method of test emphasizes *flexural* efficiency, and that columns

under compressive and flexural action together might be expected to show less variation in strength between different types of section than the variation shown in these tests.

The flexural efficiency of any column could be tested after its fabrication without injury to the column, by loading it as a beam under flexure in a plane parallel to that of the lacing, measuring deflections and fiber deformations, and comparing observed values with those obtained by computation on the basis of integrity of action of cross-section. The loads necessary to cause deflections and fiber deformations large enough to be accurately measured would not be so large that the use of dead weights would be difficult, and such measurements can be quickly and easily made, though they require great care and no small skill on the part of the observer. The writer believes that some test of flexural efficiency would be a valuable one to apply to columns, especially to those of unusual design or extraordinary size.

The variation in the value of the modulus of elasticity for different samples of steel reported by Professor Basquin from tests by Mr. J. E. Howard made at the Watertown Arsenal is large. Although it is not definitely so stated it seems probable that, following the practice which until very recently was standard at Watertown, the values of modulus of elasticity were determined from tests in which extensometer measurements were made only on one side of the specimen. From the writer's experience in making extensometer tests of steel and the tests of Prof. C. A. M. Smith^{*23}, it would seem that the value of modulus of elasticity determined from extensometer measurements on one side only of a test piece might give results as much as 10% in error. Most of the values quoted by Professor Basquin lie within a range of $\pm 10\%$ of 30,000,000.

The question of the ability of a column to carry permanently loads which cause fiber stresses beyond the elastic limit (limit of proportionality), has been raised in Professor Basquin's paper. The writer knows of no tests of columns under long continued load, but recently he has made tests of I-beams in flexure under loads which stressed the compression flanges to the yield point. The load was continued for 107 days without causing failure of the beams, and after the first few days, there was no further material increase in fiber deformation. The writer has obtained similar results with small round rods loaded as beams. Thurston^{*24} reports similar results.

The writer wishes to call especial attention to Professor Basquin's excellent analysis of the causes of stress in lacing bars. Attempts have been made to determine the law of shear in a column.

*23. C. Alfred M. Smith, "On Stress Distribution during Tension Tests." *Engineering* (London), December 10, 1909, p. 796. Also see the issue of *Engineering* for October 29, 1909, p. 593.

*24. Thurston, "Text Book of the Materials of Construction," pp. 512-3 and pp. 548-560.

with the resultant stress in lacing bars, by assuming the general shape of the bending moment curve on the stressed column and then finding its rate of change at different points, which rate of change is supposed to determine the shear in the column at that point. This method yields no indication of the magnitude of stresses caused by initial or local irregularities, which often, if not usually, cause much greater stress in lacing than does the variation in bending moment along the column.

A limitation of the applicability of formulæ used in computing the strength of structures has frequently come to the attention of the writer in the course of tests of the strength of beams and columns. The formulæ in common use concern themselves only with the stress in the most-stressed fiber, and take no account of the behavior of adjacent fibers or of the structure as a whole after the most-stressed fiber becomes imperfectly elastic. As a matter of fact, there are very few columns or beams in a steel structure which in the course of erection have not suffered local stresses beyond the elastic limit strength of the material, and the strength under *static* loads of a structural member is dependent in no small degree on the ability of less-stressed fibers to take load when the most-stressed fiber begins to yield. An excellent example of this dependence is furnished by comparative tests in flexure of a round rod and of an I-beam of the same material. The round rod will develop distinctly higher fiber stresses than the I-beam before failure occurs or before the load deflection curve departs noticeably from a straight line. The superiority of beams and columns of "stocky" section over those of "flimsy" section is very difficult to express mathematically, but the general fact of such superiority should be kept in mind by engineers.

John H. Griffith,[‡] ASSOC. M. AM. SOC. C. E.: An English engineering authority, in concluding certain of his own discussions pertaining to the mechanics of the column, has written to the effect that all other statements about this subject that he has seen, "are of infantine simplicity, but utterly wrong." This remark would appear to be rather ungenerous, considering the painstaking efforts of many of our most able and conscientious engineers covering a long period of years; and yet looking at the matter from the larger and impersonal point of view, it might serve to emphasize the fact that the research in this field, to say the least, has been rather ineffective. Furthermore, should one seek for information from those who are most competent to judge as they reveal their ideas in their discussions before the various engineering societies, he is led to feel that the whole theory of the column has been largely confined to that domain which Professor J. B. Davis, of the University of Michigan, once somewhat derisively defined as speculative mathematics. Despite a certain degree of enthusiasm with which

[‡] In charge physical testing laboratory, Bureau of Standards, Pittsburgh, Pa.

new born column formulae are ushered into the world from year to year, it is noteworthy that many consulting engineers feel compelled to be solely guided by tables of actual tests upon full size columns for trustworthy information regarding design; whereas the professor of engineering, who usually reflects what is relatively permanent in the theory of engineering, must, as in times past, announce to his classes that the column theory is in the formative and transitory stage and cannot be enunciated at the present time. Now it is the designing engineer who must feel the full onus of mysticism which has been almost invariably attached to this subject. He must design columns and be responsible for such designs. Furthermore he must spend long hours in computation to fulfill the many strict clauses of modern specifications. The writer feels that it is unfortunate, after several French engineers of a former generation have spent a great deal of time in perfecting such a simple working method as the common or Bernoulli-Euler theory of the beam, that the more recent writers along this line have seen fit to make of this a vehicle of their highly involved theorizing, elementary though it may be. An engineer who would introduce a theory of "wrinkles" into a working theory of the column should openly essay legitimate mechanics with such writers as Clebsch, Lamé or Pearson. It has been well pointed out by Professor John Perry that the "engineer recognizes from the beginning that his problems are too complicated for any exact mathematical investigation. He therefore leaves out his apparently insignificant terms rather at the beginning than the end; but indeed he leaves them out in any part of his investigation if they are likely to give trouble, for he recognizes from the beginning that his theory is only to guide him, and that the final appeal must be experiment." Upon the other hand many engineers feel that their particular formula, like, for example, that recently proposed by Dr. Lilly,*²⁵ shall include various conditions of transverse or other loading, eccentricity of application of load, etc. But in the case of infinitesimal strain, which is properly the whole scope of engineering design, all such effects might easily be treated separately, and left to the judgment of the designer. The real desideratum of the structural engineer is simple enough;—how shall he safely design a column without eccentricity of any kind, without transverse loading; sans end moments, sans wrinkles, sans lattice bars if need be. But after fifty years of research the column analysis would appear to be the most important one before the engineer of today; at least the writer gleans this idea from his correspondence of recent date with several experts.

When a theory which seems correct enough in its general formulation and detailed processes, is found to be unworkable, or at least deficient in producing or interpreting results, one may consider such a one to be improperly framed for the purposes to which

* 25. Proceedings Am. Soc. C. E., August, 1912, vol. XXXVIII, No. 6, p. 852-3.

it is to be applied. To correctly state a problem is said to be half of its solution. The late Henri Poincaré,^{*26} of the University of Paris, was wont to remark that the ancient Ptolemaic theory which conceived the earth to be at the center of the universe, was quite as true as the Copernican. The latter, however, is vastly more convenient in that it explains with far greater ease numerous phenomena such, for example, as the flattening of the earth at the poles, the principle of Foucault's pendulum, the trade winds, parallax of stars, etc., etc. Now the inefficiency of the modern column theory to produce definite results is chiefly evidenced by the great variety of well nigh absolutely inscrutable problems it has called into being. It might be compared to the Ptolemaic theory of the universe. Analytically it is like the divergent infinite series true enough, but yielding nothing.

As the experimental engineer is engaged in superintending the introduction of his column into its place in the testing machine, and watches with a certain degree of pride the careful adjustments of the machinists, who with shim and leaf gauge are quick to shut off the slightest discernible light which might possibly emerge between the carefully planed surfaces of column and testing machine platen, thus to the best of his judgment securing an appropriate bearing, how often has he felt, almost unconsciously perhaps, the possibility of lurking errors owing to elastic or inelastic displacements at the column ends which might more or less modify his data. The engineer tacitly admits the possibility of such errors. One says the hemispherical bearing should be oiled, another that it should be free from oil. And at best many screw machines are limber things which could not stand the 10% thrust often prescribed at the platens, nor even a 1% rule without appreciable deflection and consequent vitiation of results on tests. Perhaps questions of elastic stability may arise of which Mr. Ernst Jonson^{*27} has been solicitous, so that the engineer will momentarily ponder whether his proposed solution from the given data is really uniquely determinate after all, whether he or another investigator could obtain the same results again under apparently similar conditions. As he makes elaborate efforts to insure concentricity of column and machine axes after the manner of Considère, he may very properly ask why a theory should be chosen which requires so much precision with so little means of attaining it. It is not a mechanical way of going to the mathematical limit. The astronomer has a somewhat analogous problem in the perturbations owing to deflections of his telescope tube. Does he maintain the concentricity of his optic and tube axes by a rigid steel cage, as it were?

Now, there are other points which have assisted in the maintenance of a wide zone of controversy in this field, such as the question of a twist on the column and distribution of the end torques

* 26. *La Science et l'Hypothèse* (Flammarion, Paris), p. 85.

* 27. *Trans. Am. Soc. C. E.*, December, 1908, vol. LXI, p. 200.

over a built-up section. There is the question of feasibility of the determination of a deflection curve for the column, since the eccentricity, owing to aeolotropic structure of the material, is a fortuitous sort of thing and follows no law whatsoever. One might cite the case of the force of friction on large pins, in fact the entire distribution over the intrados, the tendency to infinite stress at small pins and knife edges, the question of stress in lattice bars and riveted connections. A search of the contemporary column discussions will reveal such cases in far greater profusion than are here reviewed.

Now, of course, there are extenuating circumstances in verification. In the matter of extensometers there has been no particular precision. The investigator will often use almost any gauge length, regardless of the fact of a varying stress. This apparatus is often fitted to points other than where the stress is a maximum or minimum and no particular note is made. The dials on many extensometers are inserted several inches from the column in such a way as to magnify actual elongations in a certain manner owing to curvature. And this passes unmentioned. The instruments usually are rated to $1/10,000$ inches, whereas $1/50,000$ or $1/100,000$ would be much more preferable. In fact, the writer in his own investigations has been used to working with an extensometer, of the Bauschinger type, rated to $1/1,000,000$ inches, and feels that there is a call for much more precision in ordinary respects if results are to have any value.

The data themselves are not always subject to careful scrutiny. There is often no "weighting" whatsoever of observations. The practical engineer has never been particular as to end conditions. Mr. L. D. Rights, Assoc. M. Am. Soc. C. E., in commenting upon certain tests, remarks, "Many of the tests which the author has plotted are from twenty to twenty-five years old; some of them are on plain shapes, and many of them, as indicated, are of iron. The present practice has been built up from these tests," etc. A great deal of culling would seem to be needed in the past observations.

The preceding remarks are sufficient to usher the general engineer into that labyrinth of inconsistencies and ramifications which the contemporary column theory nearly always has presented. After following these analyses and discussions in the last two decades, the writer feels convinced that their first fundamental error has been the attempt to treat the column *separatim*, i. e., detached from its mechanical setting or framework, the separation of an element as it were, from its mechanical context; and then having thus isolated such a member for study or experiment, the next erroneous procedure is the attempt to apply the formal methods of analytical mechanics to a problem which is almost entirely empirical in its scope. The present "theory" should be displaced; it is neither logical nor mechanical.

After giving considerable thought and study to a really constructive theory of the column, the writer has taken a hurried inventory of mechanics to see what is available in the way of a suitable procedure to obviate the previous difficulties and uncertainties. Two courses have suggested themselves, which can be only briefly described in the narrow limits of a discussion.

The first and most natural method, in the writer's opinion, will be to generalize the Bernoulli-Euler theory of the beam in such a manner that the column shall appear in its more subordinate and appropriate position of an element in the analysis of a network or aggregate of articulated bars, just as a single beam is an element of the continuous girder. For example, the ordinary continuous column might be called a linear, the ordinary truss in two dimensions, a uniplanar, and the three dimensional truss, a spatial aggregate of bars, using common terms of mechanics and mathematics. The calculation of longitudinal stresses may be made by well-known methods. It will be more necessary to devote attention to the twists and bendings of the members.

Now, the most general point of view often brings before one certain difficulties or limitations that do not appear in the particular cases, although such general problems cannot always be immediately computed in every case. The most general case of the column as it applies to the engineer will be its analysis as an element or member of a three dimensional truss. Such a truss will be assumed statically determinate for convenience, *i. e.*, it will consist geometrically of a group of tetrahedrons. As such a truss is strained through the longitudinal distortions of its members, each joint will suffer a rotation combined with a translation parallel to the axis of the rotation.*²⁸ In general, each bar will be strained to a tortuous curve approximating a spiral, *i. e.*, a line wound around a surface of revolution with a variable pitch. The strained deportment of the truss may be simulated by a model truss made up of adjustable telescopic rods rigidly fixed at joints, which rods may be given arbitrary increments over an initial unstrained configuration, the rods for a given position being clamped by set screws. If a closed surface is made to include a joint, conveniently taken so it shall normally intersect the members radiating from that joint, then the stresses upon the free body or joint so excluded will form a system in equilibrium, and were the various forces, moments, shears and torques known they might be combined or geometrically added by well-known methods of mechanics, also the strained position calculated.*²⁹

In order to obtain an idea of the stresses existing upon such a surface or boundary excluding the joint, reference must be made to the elastic theory of thin rods which experience both twisting and

*28. See Ziwet's *Mechanics—Kinematics*, p. 39.

*29. Such methods are given in Ziwet's *Mechanics* under the mechanics of rotors, couples, etc.

bending. The theory of the subject is largely due to Gustav Kirchhoff.*³⁰ One can get a fair idea of the strained position of a truss member by taking a thin flexible stick, bending this in the hands, say, to a flat *S* curve, and simultaneously applying a twist at each end. The rod or member is supposed to be held in equilibrium by end stresses alone. These stresses are statically equivalent to a force acting at the centroid of the end area and a couple.*³¹ Now, if a coordinate system is assumed, having the axes *x*, *y*, *z*, the force and couple when known may be resolved along these axes into "direct stress," shears, flexural couples, and a torsion couple. The *z* axis is usually taken tangent to the strained central line or column axis, the plane (*x*, *z*) being a principal plane of the rod. These axes constructed in the above manner at any point on the strained central line are known as the principal torsion flexure axes for the rod at the point in question, and the general problem is to obtain stress relations which shall apply to any member of the truss, write these for all the members, and then find sufficient additional relations to effect a solution of the unknowns by the conditions for joint equilibrium previously mentioned. Professor Love has suggested the approximate theory, which consists, as in the ordinary beam theory, of connecting the stress couples at any point with the

components of curvature, this being the familiar $\frac{M}{EI} = \frac{1}{R}$ rela-

tion of the common beam where *M* is moment and *R* the radius of curvature. The real difficulty will be to obtain a relation between the torsional couple and the twist for a built-up section, as de St. Venant's torsion studies apply only to prisms. This problem can only be solved at present, it is believed, in the case of a truss whose members are either solid or hollow cylinders. It is nevertheless important for a view-point, in that it shows a rather speedy limit to such general analyses of flexure as that presented by Professors Tilden, Johnson, Kinne and others, except in the case of ball and socket ends, on account of the twist. Very lately Dean M. E. Cooley has suggested the importance of tests on square, triangular, and other prismatic shafts. The writer believes that the built-up shape must be studied for torsion, and that such studies will play an important part in explaining certain discrepancies between figures and fact in the column theory. The subject can best be approached from the experimental side by the engineer.

Considering now the more practical aspect when the solid truss

* 30. "Über das Gleichgewicht und die Bewegung eines unendlich dünnen elastischen Stabes," Crelle's Journal Math. (1859), also Kirchhoff's Mechanics.

* 31. This subject has been well discussed by Prof. Love, "Theory of Elasticity," chapter XVIII, to which the writer has referred. The geometry of the curves is discussed by C. Smith, "Solid Geometry," chapter XI. Also see Routh's "Dynamics," part II, chapter I.

degenerates to a plane truss, viewing this as a limiting case. There are, of course, lateral displacements of the strained central lines of members, also twists in each member, but properly such elements are foreign to a uniplanar analysis. Manderla*³² has discussed a phase of this problem upon the assumption that the strains, owing to transverse and longitudinal shears, the twists, and strains in end riveted gusset plates be allowed to vanish, in the following manner. A closed curve intersecting the various members normally may be passed around each joint. At the end of each member thus cut out there is a force and a couple. The force resolves longitudinally and transversely at the centroid of the end sections. The couples may be expressed as a function of the angular displacements of the central lines owing to strain as follows:

$$M_{na} = E_{na} \frac{I_{na}}{l_{na}} (K_{na} \tau_{na} + K_{an} \tau_{an})$$

where

n refers to any joint in the interval o to t ,

a refers to an adjacent joint,

na (accordingly) represents any member radiating from a joint n ,

l_{na} represents the length of member,

M_{na} is the moment or stress couple at the end n of the member,

E_{na} is the modulus,

I_{na} is the moment of inertia,

τ_{na} is the angle between the line na connecting joints after strain and the tangent to the elastic line at n ,

τ_{an} is the same angle for reversed length or member an ,

K_{na} and K_{an} are constants to take account of what the engineers call secondary flexure.

Now, applying the conditions of equilibrium to each joint by taking account of the forces, couples, shears on the boundary formed by the closed curve, the longitudinal forces at the centroids balance by statics. If the closed curve is contracted to smallness the moments of the shears about the joint tend to vanish, leaving:

$$\sum M_{na} = \sum \left[E_{na} \frac{I_{na}}{l_{na}} (K_{na} \tau_{na} + K_{an} \tau_{an}) \right] = 0.$$

where there are as many terms in the sum, of course, as there are members radiating from each joint. There are t equations, *i. e.*, as many as joints in the truss, and conditions of symmetry usually considerably reduce these. Sufficient equations to effect a solution exist by reason of the fact that any τ_{na} can be expressed as the sum

*32. "Lösung der Preisaufgabe: Welche Spannungen entstehen in den Stäben eines Fackwerkträgers dadurch, dass die Winkel der Fachwerkdreiecke durch die Belastung eine Änderung erleiden"? Jahresbericht der Münchener Techn. Hochschule, 1878, also Engesser's "Zusatzkräfte und Nebenspannungen."

of some initial τ_{na} arbitrarily chosen, and the angular strain which has occurred between members na_0 and na_r owing to direct stress in the members of the truss. The details of this method may be found in the elementary works on structures and will not be given here.*³³

Certain of the above essentials were published in America by Bender in the *Railroad Gazette* as early as 1884, but no one seems to have taken it very seriously in connection with an appropriate analysis of the column. It is important, therefore, to examine this method somewhat critically in this connection.

In the first place the material may be assumed isotropic. One may "lose in the shuffle" such items as an arbitrary or prescribed eccentricity which looms so large in Professor Basquin's, Mr. Ernst Jonson's and many other view-points, just as de St. Venant and others excluded aeolotropicity of structure in the common beam. They left the latter assumption to the mathematician. The theory presents no dilemmas as to concentricity of axes nor end conditions, nor what happens especially at zero or infinity, for things are perfectly determinate throughout for the entire range of practice. The principle involved is so flexible that it may satisfy either the practical engineer or the elastician. The discovery of a torsion formula for built-up shapes might be easily applied, using the principle of superposition of small strains. The lateral strains would usually be small compared to the strain in the plane of the truss. Engesser gives formulae for external loads. The question of pin friction, eye bar friction, etc., are determinate. The theory applies to redundant structures of all kinds, arches, etc., for it is the general analysis of the beam extended to spatial frames as well as to a pillar or strut, and one can obtain any deflection curve found in any true column theory based on the Bernoulli-Euler hypothesis by an appropriate selection of data and terms. In the writer's opinion this is the only theory which can possibly be applied to the study of lattice bars.

The chief objection to adopting such a point of view as is here suggested, of course, will be the fancied one of time for computation. It is thought, however, that no more time will be consumed than the calculation of the members of a truss, by such highly differentiated formulae as, for example, those presented by Professor Cain, Dr. Lilly, or Mr. Prichard from time to time. The practical accuracy of the method has been tested to an extent qualitatively by experiments on railroad bridges under train loads, but what is needed are quantitative values in the laboratories on $\frac{1}{4}$, $\frac{1}{2}$ or full size models. Doctor Lilly*³⁴ made some earlier tests to prove the principle of the continuous girder. It is hoped he may carry out

* 33. See Johnson, Bryan, and Turneaure's *Framed Structures*, Vol. 2, also Grimm's and Isami Hiroi's works on *Secondary Stresses*.

* 34. See Williamson's *Mathematical Theory of the Stress and Strain of Elastic Solids*, page 121.

experiments on this more general form of the continuous beam or column.

It now remains to discuss briefly the detached or individual column,—for brick piers, cast iron pillars, and isolated columns of steel or concrete will naturally come under this head. This is properly the real domain of the old theory, and will represent the practice of those who will design by formulae rather than mechanical principles.

Some 300 years ago René Descartes remarked “Lorsqu’il n’est pas en notre pouvoir de discerner les plus vraies opinions, nous devons suivre les plus probables.” (“When it is not in our power to determine what is true, we ought to act according to what is most probable.”) Such a theory can be nothing more than almost purely empirical, and to briefly rehearse the practical investigations of the last 50 years is to show the dire straits to which the engineers have been reduced in their attempts to make it rational. The first awkward step was the movement to reject the formula of Rankine,—the most accomplished engineer of his time, and one trained as an elastician and scholar as is not customary today.

The writer is prepared to agree with Mr. Henry B. Seaman,*³⁵ M. Am. Soc. C. E., that there never has been a “sufficient reason for abandoning the Rankine formula.” In the first place it is very nearly formally correct, then it satisfies both limiting conditions as to the length. Moreover, the writer believes it is easier to apply than its substitutes, for the computer can obtain his reductive factor for mean stress with one setting of the slide rule, add unity and multiply, whereas in many of the proposed expressions the operation of subtraction enters and is not amenable to slide rule computation. Admitting, however, the efficacy of rejection, what is offered in its place? Some one perhaps of the following: a family of straight line loci, or some parabolic expression, or possibly some sort of combination curve as the so-called “S. P. R.” formula; and these are followed in diffuse multiplicity by a great variety of similar curves of the different column authorities, which differ from the others too often only in the minutiae and minor details of presentation. The last term of this interesting sequence originated in Boston, the proposed curve being an ellipse in general, but more particularly the circle. The writer, however, will venture the opinion that it is more unique and praiseworthy than the rest, in that its author*³⁶ has shown a disposition to utterly detach the column of practice from any connection whatever with Euler’s purely abstract expression for very long columns. The retention of this Euler formula is chiefly of academic interest, as such engineers as Schneider, Cooper, and others, have implicitly rejected it in fixing in their various specifications lengths of $\frac{l}{r}$ such as 100, 120, etc.

If the dictum is to be maintained that all curves shall be tangent to

*³⁵. Trans. Am. Soc. C. E., Dec. 1908, vol. LXI, page 162.

*³⁶. Trans. Am. Soc. C. E., Dec. 1908, vol. LXI, page 156.

Euler's, one might equally well insist upon having some catenary form for very long beams, possibly some analysis like Professor Stokes' for the short ones, Poiseuille's law of capillarity to be included in analyses of water pipe, and a provision in Mr. Wellington's formula for the load on the pile when the penetration is zero, which case he sought, of course, to exclude. It is quite evident that unless these investigators shall appropriate certain of the transcendental curves for their column equations, the present line of column research must automatically terminate itself by a process of sheer exhaustion.

The hydraulic engineers have had a problem peculiarly their own in the attempted elimination of the so-called Kutter formula. The more liberal engineering designers have taken for their friction factor in pipes an expression of the form, $h_f = A^d B^c C^r D \dots$. Now since practically all of the formulae that the bridge engineers have seen fit to include in their specifications are really empirical in their nature, it would be well to put the column analytically on a strict empirical basis, following that most honest and distinguished investigator, Mr. Eaton Hodgkinson,^{*37} who let facts stand instead of supplanting them by purely arbitrary assumptions. The important discovery since Hodgkinson's day is that column stress consists of direct stress superposed on a stress couple as given by the

$\frac{P}{A}$

common law of the beam. The direct stress— is strictly rational

from the standpoint of the Theory of Elasticity for an isotropic column. The variation in an actual column would be very small and can be neglected. The expression for bending could easily be put in the exponential form, letting the exponents of the various necessary variables be found by experiment by well-known methods of Experimental Physics. The main variables would be the length in the numerator raised to some power, and the extreme depth and possibly width both raised to suitable powers, with a constant. The term radius of gyration being a function of the limiting dimensions of the section might be conveniently dropped, as it is closely equal to the depth times a constant for columns of similar section. It would never be missed. Such a formula would be closely of the Rankine form but would stand for facts rather than theory. Those jagged serrated deflection curves occasioned by improperly designed lattice bars would curve themselves to the average tendency in a sufficient number of experiments. If knife edge bearings were used, as is well suggested by Mr. E. Jonson, a column would be tested under perfectly definite conditions. The writer has used single ball bearings for circular concrete columns with good results. The pin, square, and fixed bearing do not define the end conditions. Such a formula as is here suggested has all

* 37. Phil. Tran. Royal Soc., London, 1840, page 227.

of the advantage of a straight-line expression because of the use of logarithmic platting or cross section paper. It has all the good features of the Rankine Gordon form without its assumptions. Moreover, the great amount of time spent in calculation of the radius of gyration might profitably be put to better use.

R. S. Chetw (M. AM. SOC. C. E.): This paper is a most valuable one, as it tends to place the analysis of columns on a plane with that of beams, and the writer hopes that the profession will give this article due consideration.

Our column formulae now used are easy of application and in ordinary cases safe. Here their virtues cease. They are empirical and based on the results of tests with little regard to the actual faults in the pieces tested. How many of our younger men understand why a compression member deflects under load? How many of our schools, in deriving the different column formulae, bring out why the bending or deflection takes place?

It seems to the writer that the author has succeeded in making these matters clear, and he believes that a column formula that allows for the imperfections cited in this paper, will be far more satisfactory than the formulae used at present.

At about the time Mr. James Howard presented his paper to the American Society of Civil Engineers, the writer had written a paper on columns. His paper came in at the same time as Mr. Howard's, so was withdrawn, the writer sending in a discussion in its place. The paper referred to contained the following derivation for column formulae, which it will be seen is similar to Professor Basquin's:

Assume a column supporting load P and having the following properties:^{*38}

- First. Initial stresses in material due to manufacture.
- Second. Variation in strength of component parts of section.
- Third. Crookedness of component parts.
- Fourth. Crookedness of whole member.
- Fifth. Local stresses due to details and shop work.
- Sixth. Accidental eccentricity.

l = length

r = least radius of gyration

c = distance from gravity axis to extreme fibre

A = area of section

to have the following imperfections:

Kink = k . See items 3 and 4.

Eccentricity = v due to items 1-2-5-6. Assume k and v to be on same side of axis, then the bending moment from these $M = P(k + v)$. This causes bending which will increase until balanced by internal stresses. (See Fig. 25.)

Let y = this increase of deflection, item 7.

*38. Transactions Am. Soc. C. E., Sept. 1911, vol. LXXIII, p. 469.

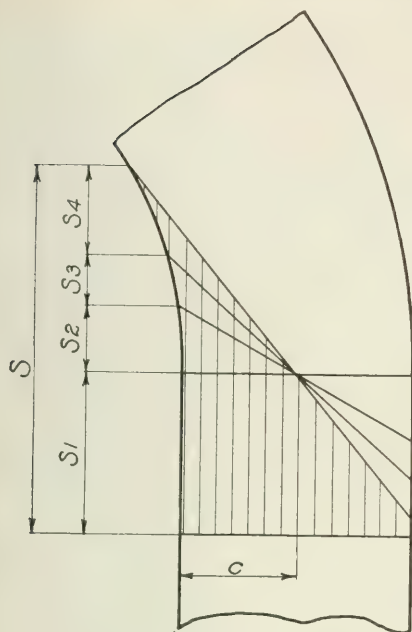


Fig. 25.

Then from Fig. 25 we have

$$S_1 = \frac{P}{A}$$

$$S_2 = \text{stress from } k = \frac{P \cdot k \cdot c}{A r^2}$$

$$S_3 = \text{ " " } v = \frac{P v c}{A r^2}$$

$$S_4 = \text{ " " } y = \frac{P y c}{A r^2}$$

$$S = S_1 + S_2 + S_3 + S_4$$

$$= \frac{P}{A} \left[1 + (k + v + y) \frac{c}{r^2} \right]$$

$$\text{Let } (k + v + y) = z$$

$$\text{then } S = \frac{P}{A} \left(1 + \frac{zc}{r^2} \right) \dots (1)$$

$$\text{From mechanics we know that } y = \frac{S_4 l^2}{10 E c}$$

$$\text{If, now, we assume that } k + v \text{ varies as } (S_2 + S_3) \frac{l^2}{10 E c}$$

(which assumption is not correct) then Formula (1) will become

$$S = \frac{P}{A} \left[1 + \frac{(S - S_1) l^2}{10 E r^2} \right] \dots \dots \dots (2)$$

which by reducing becomes either Euler's or Rankine's formula, depending on assumptions.

Referring now to the above, we see that M at center $= P z$ and at any point being $P \int (z)$

The writer believes that the bending of column is entirely due to this bending moment or that the formula for an ideal column,

i. e., a column perfectly straight and homogeneous, is $\frac{P}{A}$, then we

$$\text{can say that } P z = \frac{w l^2}{8}$$

where w is a load that applied transversely per foot of length would produce a moment equal to $P z$

or $w = \frac{8 P z}{l^2}$; therefore we have column loaded as indicated in Fig. 26

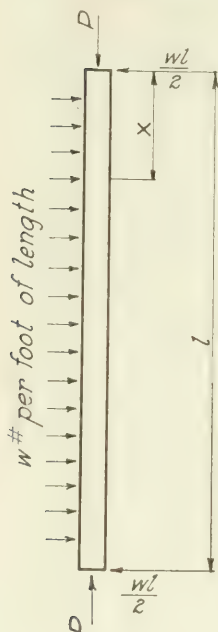


Fig. 26.

$$\begin{aligned} \text{Moment at any point} &= \frac{w x l}{2} - \frac{w x^2}{2} \\ &= \frac{x}{2} (w l - w x) \text{ or} \\ &= \frac{w}{2} (x l - x^2) \end{aligned}$$

$$\text{but } w = \frac{8 P z}{l^2} \therefore 4 \frac{P z}{l^2} (x l - x^2) = M$$

$$\text{but } S = \frac{M c}{A r^2}$$

$$\text{and formula} = \frac{P}{A} + \frac{4 P (x l - x^2)}{A l^2 r^2} z c = S$$

$$\text{or } S = \frac{P}{A} \left[1 + \frac{4 z c (x l - x^2)}{l^2 r^2} \right] \dots \dots \dots (3)$$

When $x = \frac{1}{2} l$, we would get the last item

$$\left\{ \frac{4 z c l^2 \left\{ \frac{1}{2} - \frac{1}{4} \right\}}{l^2 r^2} \right\} = \frac{4 z c l^2}{4 l^2 r^2} = \frac{z c}{r^2}$$

$$\text{or } S = \frac{P}{A} \left(1 + \frac{z c}{r^2} \right) \dots \dots \dots (1)$$

Using Formula 3 in conjunction with tables of Eulerian Secants and a value of z agreed on, it appears to the writer that the column could be analyzed for stress at any point. We could then see clearly just how the variation of stress took place and could place our material at such place as to give most efficiency.

The writer is thoroughly in accord with the author in his conclusion, and it is to be hoped that he will now have a series of tests to determine the limit of the different eccentricities.

Horace R. Thayer (Asst. Prof. Structural Design, Carnegie Institute of Technology): The author has certainly rendered the profession a very great service in calling attention to some of the reasons for the low ultimate stress in columns, and especially in built-up columns as they occur in our modern structures. It is true that similar conditions often surround tension members. However, the effect here of the principal stress is to lessen the secondary values, whereas in struts the opposite is the case.

I wish to inquire if the "accidental eccentricities" should not be as often negative as positive if we accept Professor Basquin's theory? Also, may not the testing machine itself have an "accidental eccentricity"? It would seem as though a great deal of valuable information might be acquired by testing columns machined to be exactly straight, and connected by rivets driven through holes drilled in place. Then let this be mounted in the machine as in Considere's tests. If, now, these columns were placed vertically so that under small loads no lateral deflection occurred, we have almost entirely eliminated eccentricity of testing machine and those imperfections which Mr. R. S. Chew mentions as causing the "accidental eccentricities." Such tests would give:

(1) The strength of a column fabricated and erected under ideal conditions.

(2) Some idea as to the commercial value of more accurate shop processes.

(3) Better comparative results for tests of different details which would not then be influenced by accidental faults in other parts of the column.

The writer does not agree with proposed rational design of columns. There are more chances for errors of judgment in all four processes, for each of which an estimate is necessary. Nothing simpler or more nearly correct can be conceived than using unit stresses and reduction formulae obtained from tests of full-sized similarly-designed columns, if they are available. Also, there is more likelihood of mistakes and inaccuracies in the four steps.

I would like a little more light on the differences between present and proposed methods of design. Could an instance be given in which the usual methods would lead to serious error? Would it not be better to put the designer's time,—if he can find any to spare,—on methods of reducing the very serious eccentricities and secondary stresses which are present in almost endless variety in every structure?

A. W. Carpenter (Engineer of Structures—New York Central and Hudson River R. R.): This paper is a valuable addition to the literature on the strength of structural metal columns. The very serious effects of relatively small eccentricities of loading are strongly presented and very clearly and completely analyzed. The author also shows very conclusively that eccentricities of loading in some degree or other are practically unavoidable. The immediate

result is wonder that more columns have not failed and some uneasiness as to the usual method of designing columns.

Upon further reflection, however, the fact that failures of columns in structures properly designed for the prevailing working "average" unit stresses have seldom, if ever, occurred as a result of the loads for which they were designed, becomes reassuring. Further, in the case of railroad bridges, when one considers the fact that such, all over the country, have been subjected to loads far greater than those for which they were designed, with no case of a column failure, due to the application of such loads in the proper manner, being recorded, so far as the writer is aware, one becomes more reassured that our methods are safe. The design of columns has doubtless improved greatly in recent years, especially in the details, so that, for columns in ordinary structures, designed for central application of loads, it would seem well established that the refinements proposed by Professor Basquin are not necessary and would result in waste of time and money if generally applied in practice.

For cases in which eccentricity of loading is intentional or can be foreseen to be probable beyond that due to the ordinary defects of workmanship, materials and theory of stress action, the analyses of Professor Basquin apply very properly, and his paper is to be recommended as a reference for treatment and formulae. A case which would probably fall in this class would be that of the expansion end of a truss or girder supported upon a column. Even in

these cases, within the ordinary working limits of $\frac{l}{r}$, in which the

deflection due to bending is negligible, it would seem that the ordinary working-unit-stress method would apply, by reducing the permissible average stress by the amount of the extreme fibre stress due to bending. This makes a simple matter of the calculations and conforms to the established methods of proportioning.

The writer agrees with Professor Basquin in his criticism of the usual specifications for workmanship on columns in regard to "bends," and believes the suggestion as to a definite limit for crookedness a valuable and practical one and that it should be acted upon by those in charge of the revision of specifications.

In regard to the variation of elasticity in iron and steel, it would appear unfortunate that Professor Basquin quoted as he did from Mr. Howard's paper without (apparently) noting what Mr. Howard himself said, in his closure of the discussion on his paper, regarding the evident inaccuracy of the values for modulus of elasticity given in the specimen-test reports recorded in the paper. Mr. Howard stated as follows: "Obviously the moduli of elasticity reported should not be accepted" and "concerning the modulus of

elasticity, careful determinations indicate a value in the vicinity of 29,500,000 to 30,000,000 lb. per sq. in. for steels of the usual range of carbon content."

Regarding the proposed grading of columns for strength according to type, the present test data are so conflicting that it seems that we are hardly in a position to do this with any degree of certainty at the present time. The writer some years ago called attention to the apparent superiority in strength of two-segment, symmetrical, latticed columns over box columns, I-columns, and unsymmetrical, two-segment-and-one-cover-plate columns in the Watertown tests (*Engineering News*, April 9th, 1908). On the other hand, anyone who has seen bent lattice bars in a column must have a feeling that solid web diaphragms are more dependable for connecting the segments of columns, and that latticing, when used, should be of stiffer sections than the ordinary flat bars.

Stockiness of material is a matter the author has not more than touched upon and which is doubtless one of great importance. Tests of record seem to indicate no superiority in strength of solid sections, such as rolled H-columns and lap-welded tubing, over built riveted sections (except perhaps for very short length ratios), nor any necessity for deducting filled rivet holes in considering the section of the latter (see *Proceedings American Society for Testing Materials*, vol. IX, 1909, page 418, Howard on Tests of Steel Columns.)

The paper is confined to the subject of columns, which, of course, includes the members in trusses which carry axial compression. Its object is apparently to question the usual method of designing such members as producing members of desired strength, on account of imperfections of workmanship and loading. It is not mentioned that these same imperfections apply to the tension members, especially if of built-up, riveted sections, and that the same variations of stresses in the sections may be expected, except stresses due to the deflection of the member which for ordinary limits of construction are taken care of by the usual specifications (in the column formulae). As the tendency of the times is to consider the compression member the weaker of the two kinds, and this paper is in accord with the same, it seems apropos to bring in to the discussion the question of the relative unit stresses to be used for the two classes of members.

As the writer views the matter, the author's points against the compression members would also apply largely to the riveted tension member. This includes the "stress due to fabrication" mentioned by the author, as well as eccentricities. The secondary stresses in structures affect both kinds of members. The segments of the tension members are generally flimsier and less strongly connected than those of the other kind, thus making them more apt to be crooked or bent and more liable to accidental injury than the

compression members. Although increase in normal stress tends to straighten tension members, while generally increasing the bends in compression members, and while there is further safety in the strength of tension members beyond the yield point, on the other hand the tension member is liable to rupture from stresses below the yield point, due to flaws, cracks, or other defects of material or workmanship, from which the compression member would not suffer. An illustration of this point is the case of a column tested by Mr. James E. Howard and reported in the *Proceedings of the American Society for Testing Materials*, vol. IX, 1909, in which a lap-welded tube column of 5 in. outside diameter, 20 ft. 6 in. long

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with $\frac{l}{r} = 150$, was cut transversely in the center of its length,

r

the ends simply butted together, and the two parts tested as a single column with flat ends, showing greater ultimate strength than duplicate columns of integral section. The maximum average strength per square inch for this column was 29,280 lb. and it carried, unrestrained between end bearings a deflection of 2.94 in. (at a lower stress after passing the ultimate). It would seem that a crack in a compression member would be less serious than the complete division of the section, as in the above described test.

It would seem probable that impact effects and repetitive loading are less dangerous to compression than to tension members. The instantaneous maxima of impact effects would not give time for column failure when they would not allow time for stretch and would consequently rupture tension members, and repetitive loadings would work a rupture from a flaw in a tension member when no such action is conceivable in the compression member.

These foregoing reasons lead the writer to think that tension members,—at least those of built-up, riveted sections,—should not be worked at much higher average stresses than compression members, and he does not think the values now in common use too high for ordinary steel structures. However, the one notable specification which allows 24,000 lb. per sq. in. as the basic unit stress in compression formulæ for dead loads, the writer believes a source of danger, and that the only thing that has saved from disaster structures designed by this specification, has been the usual small ratio of the dead to the assumed live load.

The author merely mentions the effect of secondary stresses. With the large riveted joints and deep, stiff members frequently required in modern riveted trusses, these stresses become a serious matter and, the writer believes, should be more generally calculated and proportioned for than is usually done. Members subjected to serious secondary stresses, which should be taken into account, are columns supporting beams or girders which are knee-braced, or

otherwise rigidly connected to their tops; also stiff tension members carrying beams or girders rigidly connected to their ends (such as floor beams of a truss bridge); especially (in both cases) when the beams are shallow and carry high stresses. The attached calculations, illustrating the secondary stresses in columns of the first class mentioned in the preceding sentence, may be found of interest; these calculations were prepared by Mr. H. S. Richmond, one of the writer's assistants. It will be noted that in this example, which is a typical one, the secondary maximum fibre stress is nearly double the average unit compression. An inspection of the formulæ will show that increasing the column section has little effect in reducing the fibre stress. The only effective theoretical way to reduce these fibre stresses seems to be by increasing the stiffness of the girder, which would be accomplished most economically by increasing its depth. However, doubling the depth, with the other conditions as stated in the problem, would only cut the fibre stress in two. Just what reduction of stresses would obtain in service due to rotation of foot of column, yielding of connections, etc., appears impossible to determine, although there undoubtedly would be such compensations, since the design is a common one and the secondary stresses seldom considered.

It appears possible that opportunity for testing the strength of columns under the load of superimposed beams and of columns and other members *in actual structures* will be provided by the construction of a 4,000,000-lb. transverse testing machine which is being proposed by the United States Bureau of Standards. Many of the questions brought up by Professor Basquin, and by the writer, should be answered by tests of members loaded under service conditions or by tests of structures as a whole, which it would seem could be brought about by a machine such as that mentioned.

Lewis E. Moore, M. W. S. E.: It has seemed to the writer for a long time that the methods ordinarily used in designing columns are, to say the least, in a large degree unscientific. As Professor Basquin points out, our method of procedure is to consider the probable slenderness ratio, select a formula, put most of the material as far from the gravity axis as possible, use batten plates with closely spaced rivets at the ends, guess at the size of lattice bars, and keep their inclination from becoming too great. These so-called principles taken with a large proportion of faith give us results in which we have confidence and may even at times point to with pride. We really have very little idea what the actual stresses are in columns so designed. In some cases doubtless this ignorance is bliss. The various tests of columns which have been made give us more or less reliable data, varying within considerable limits, which we may use in designing columns of a form and use similar

to those tested. But who can say what the factor of safety will be when such a column is used as the top chord of a bridge? In such a case the deflections of the panel points will give conditions vastly different from those met with in the column of similar section which is tested in a machine; and it may not be safe to rely too implicitly on the test in designing the chord. The difference in fundamental conditions must be carefully considered in such a case.

The column formulae in common use all assume, in one way or another, that there is a deflection of the column under load and also that the load is axially applied. These are two mutually contradictory conditions. Professor Basquin's method is certainly more logical, and if it be handled intelligently and with knowledge and good judgment it should help a designer to produce results which are superior to those attained by the commonly accepted methods. These ordinary methods have, however, the advantage that they can be applied by comparatively inexperienced men with reliable results in usual cases.

In reading over this paper (and now I am speaking from the standpoint of a designer), it occurred to me that the attempt to allow for variations in the moduli of elasticity is fraught with many difficulties of a practical nature and would better be omitted in most practical cases. The real difficulty in applying this method lies in determining the proper eccentricity to use. With our present knowledge, the fundamental difference in the methods, from one point of view, lies in substituting one guess for another.

The next need of the profession is more knowledge concerning the proper amount of eccentricity to assume for various forms under various circumstances. It has seemed to me for some time that what the profession needed was not so much more column tests, as better interpretation of the tests that have been made. What seems to be a method of securing this better interpretation has been presented to us in this paper.

It now remains to apply this method to the data already available, in order to gain information concerning the probable amount of the accidental eccentricity. If the information so gained proves to be sufficiently definite to enable reasonably dependable conclusions to be drawn, it will be quite certain that we have an improved method of dealing with a vexed question.

Edward Godfrey (M. AM. SOC. C. E.): With the last paragraph of Professor Basquin's paper I am heartily in accord. The whole tenor of a paper of mine, published in the *Railroad Age Gazette*, July 2, 1909, was exactly along the lines of this concluding paragraph. I tried to urge upon the engineering profession that the essential thing to take into consideration, in investigating the strength of a column, is the imperfections "both with respect to its manufacture and with respect to the manner of loading." I recommended that it be assumed that in the manufacture of a col-

516A



of Angle α (See figure)

in of axis of girder
stant by hypothesis.

and determining the constant
placing $\frac{dy}{dx} = 0$ when $x = \frac{L}{2}$

$$\frac{dy}{dx} = \frac{MA}{2EIg} = \alpha$$

$$\text{it stress in girder} = \frac{MD}{Ig}$$

$$\frac{100 \times 15000}{30,000,000} = .005$$

$$T_1 = \alpha \left(1 + \frac{D}{L}\right) = .00583$$

$$T_2 = \alpha \frac{D}{L} = .00083$$

$$+ n_c T_2 = 2,760,000 \text{ " \#}$$

$$+ n_c T_1 = 1,695,000 \text{ " \#}$$

as in top of column =

$$10 \div 113 = 24400 \text{ \#/sq"}$$

$$\text{ess} = \frac{13400 \text{ \#/sq"}}$$

$$\text{it stress} = 37800 \text{ \#/sq"}$$

Note: This theoretical treatment of bending in this column is rigorous except that the resistance of the column to deflection of the girder is not considered. The bending effect of the moment of the axial force into the ordinate of deflection is considered.

For theoretical analysis, see
Secondary Stresses in Bridge
Trusses 1908 by C. R. Grimm.

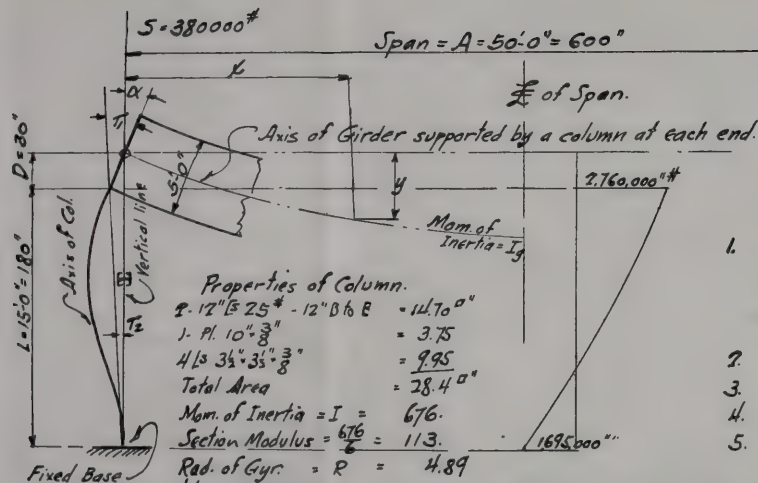
STUDY OF SECONDARY BENDING STRESSES IN COLUMNS.

pp. 26 & 27.

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5-20A



Properties of Column.
 $12 \times 12 \text{ S } 25 \text{ L} - 12 \text{ B } 16 \text{ E} = 14.70 \text{ sq}''$
 $1 \text{ Pl. } 10 \times \frac{3}{8} = 3.75$
 $4 \text{ Ls } 3\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{8} = 9.95$
 Total Area = 28.4 sq''
 Mom. of Inertia = $I = 676$
 Section Modulus = $\frac{676}{6} = 113$

Rad. of Gyr. = $R = 4.89$
 $L/R = 180 \div 4.89 = 37$ ~MOMENT DIAGRAM~

Total Axial Compression = 380,000 #

Average Unit " = 13,400 #/sq''

* $\rho = \frac{L}{EI} = \frac{L}{R \cdot \frac{13400}{30,000,000}} = 0.78$

* $m_c = \frac{4}{\rho} - \frac{2}{15} \rho - \frac{11}{6300} \rho^3 = 5.02$

* $n_c = \frac{2}{\rho} + \frac{1}{30} \rho + \frac{13}{12600} \rho^2 = 2.59$

~Conditions of Loading of Girder~
 Joists assumed to carry a stress of 15,000 #/sq'' (gross section). Unit stress constant along entire length.

Determination of Angle α (See figure)

- General equation of axis of girder
 $\frac{d^2y}{dx^2} = -\frac{M}{EI_g} = \text{constant by hypothesis.}$
 Integrating (1) and determining the constant of integration by placing $\frac{dy}{dx} = 0$ when $x = \frac{A}{2}$
- $\frac{dy}{dx} = -\frac{M}{EI_g} (x - \frac{A}{2})$
- when $x = 0$ $\frac{dy}{dx} = \frac{MA}{2EI_g} = \alpha$
- but $f = \text{max. unit stress in girder} = \frac{MD}{I_g}$
- $\therefore \alpha = \frac{Af}{2DE} = \frac{600 \times 15000}{60 \times 30,000,000} = .005$

From figure $\tau_1 = \alpha (1 + \frac{D}{L}) = .00583$

$\tau_2 = \alpha \frac{D}{L} = .00083$

* $M_1 = TSEI(m_c \tau_1 + n_c \tau_2) = 2,760,000 \text{ #}''$

$M_2 = TSEI(m_c \tau_2 + n_c \tau_1) = 1,695,000 \text{ #}''$

Bending stress in top of column =

$2760,000 \div 113 = 24400 \text{ #/sq}''$

Axial unit stress = $13400 \text{ #/sq}''$

Max. total unit stress = 37800 #/sq''

Note: This theoretical treatment of bending in this column is rigorous except that the resistance of the column to deflection of the girder is not considered. The bending effect of the moment of the axial force into the ordinate of deflection is considered.

For theoretical analysis, see Secondary Stresses in Bridge Trusses 1908 by C. R. Grimm.

STUDY OF SECONDARY BENDING STRESSES IN COLUMNS.

* See Secondary Stresses in Bridges 1908 by C. R. Grimm. pp. 26 & 27.

Office of A. W. Carpenter

Mar. 5. 1913.

umn an eccentricity of $1/400$ of the length is apt to result, and lack of centering of the axial loading may bring this eccentricity up to $1/300$ of the length.

On this simple postulate a very complex formula was worked out, a formula entirely too cumbersome to use in practice. The locus of this formula was plotted, and it was found that up to

$\frac{l}{r}$

about a value of 100 for — the agreement with the commonly used straight line formula was practically identical; but little deviation

$\frac{l}{r}$

was shown up to — = 150. The curve of this formula was peculiar,

having so large a part of its length almost absolutely straight. In my deductions I did not assume that my column was frozen absolutely rigid with a bow $1/300$ of its length, as others have done, deducing results of no value, but I took into account the fact that the endwise load will augment this deflection by an infinite series. This series is vanishing for any fractional increment to the original deflection, but for a load that would double the original deflection, the sum is infinite. In this way it is proven that a load that will double any initial bow in a column, no matter how minute that bow may be, is the extreme ultimate load that the column can take. This is practically the Euler load. (Engineers have a vague idea that the Euler load is the buckling strength of a column. I have never seen a derivation of the Euler formula that demonstrated anything. Such derivations may exist, but the samples I have seen are not among them).

I submitted my deductions to the engineering profession as a contribution to the subject of the strength of columns and a substantiation of the "empirical" formula in common use, with the hope (a very faint one) that book writers, and others who come out periodically in print with exceedingly complex formulae for the strength of columns would turn their attention to the imperfections of columns and of necessity simplify their mathematics, instead of covering these imperfections with intricate webs of so-called rational formulae, impossible of practical use.

The simplification of the mathematics that should logically follow a shifting from pure theory to consideration of imperfections is brought about by sheer necessity. There are endless ways in which a column may be imperfect or lack homogeneity, and the possibilities of the mathematician amusing himself along these lines will hold out until doomsday. The man who is designing columns for public consumption will demand a simple and workable formula. The simplest and commonest imperfections in rightly built columns is lack of straightness or lack of central application of the load. If a formula covers this, it is all that practical engineers can hope to have. As I stated in my paper, already alluded to, "a

perfect column formula is neither a possibility nor a desideratum. If a perfect column formula were possible, only a perfect column would satisfy it."

A large part of the literature on the strength of columns could be rightly termed, "An investigation of the ultimate strength of carefully made nursery columns subject to endwise load, perfectly centered in a testing machine of the most perfect manufacture possible." This is especially true of literature on reinforced concrete columns. There is about as much relation between the condition of a concrete shaft in a testing machine and one in a monolithic building as there is between a life boat on a rolling sea and the arrangement by which students develop their rowing muscles in a gymnasium. There is not a great deal more of similarity between steel columns in a structure and in a testing machine. This is not written to discredit laboratory tests; they are eminently useful. It is written to discredit the standard method of arriving at deductions and conclusions, in other words, of interpreting these tests.

Interpreting the meaning of tensile tests is a simple matter. In a large measure it is true that if one square inch of steel in tension resists an ultimate load of x pounds, y square inches will resist xy pounds. Tension members even tend to minimize or overcome their imperfections under the force that tends to rupture them. To so large an extent is this true that the writer is familiar with some tests on bent bars that stood many times their calculated ultimate load, because the bars were tough enough to straighten out, partially, before failure. Compression members—particularly those of the lengths commonly used in structures—are quite the reverse. Imperfections are magnified by compression loads. If a column is bowed, application of the load will augment that condition. Hence it is necessary to define sharply, comparison of tests and structures as between tension and compression members. Furthermore, there are certain details which, if not properly carried out, may make the results of tests of little, if any, practical value. Just as a beam tested without having its compression flange braced will give results that bear no relation to the strength of a beam that is properly braced, so a column not properly designed gives results that are of value only as they point out that such methods of designing columns should be eschewed.

Along this line, some tests on columns, described in Bulletin No. 44, University of Illinois Engineering Experiment Station, are on columns having web plates with a width between rivet lines 50 times the thickness of plate and lattice bars, with a distance between end rivets 70 times their thickness. Local crimping of these thin sheets gave stresses in lattice bars that represented transverse shears 2% or 3% of the axial load on the column.

Also this crimping caused failure at a low load. Now, specifications long ago required that plates be limited to 32 or 40 times their thickness as the width between rivet lines, and that lattice

bars be not more than 40 times their thickness between end rivets. The engineering profession does not need these tests to prove that such flimsy plates and slender lattice bars are unsuitable for compression members. They worked that out long ago by experimenting with the elements of a column, and no amount of tests on full-sized columns can prove it any more than it is proven already by these experiments.

Tests of full-sized members should be on rightly designed members, as such design is now understood and practiced; then if any weakness develops in such design, the way to advance column design may be pointed out. The same bulletin describes measurements on lattice bars in an actual structure under stress. No measurable stress could be detected.

The engineering profession is not nearly so ignorant of the strength of full-sized compression members as some of its members would have us believe. It is true that the exact ultimate strength of columns (not slender) cannot be accurately told, but it is just as true that a perfectly safe column can be designed and built for any given load without wasting material, and this is the kernel of the matter so far as designers are concerned.

If more attention were paid to rational applications of theory already known in the design and proportion of columns, vastly more progress would be made toward safe and sane design than the never ending exhibits made with flimsy channels held at intervals by little batten plates, and when one fails, an eminent authority says that "the use of tie plated columns, when the section is assumed to be integral, may lead to constructions which do not afford adequate security under loading of unusual character." The "unusual character" of the loading was that it was subject to the attraction of gravitation in a direction directly through the axis of the column. (See *Engineering News*, July 27, 1911). An authority not so high could have asserted without the least fear of contradiction that these columns were abominable and dangerous and should not have been required to support any considerable load.

If writers busied themselves with showing when a column is of a certain ratio of slenderness and with emphasizing the fact that almost no columns in structures are really fixed-ended, engineering would be saved many a shamed face. It is here that the laboratory and the structure are differentiated. It is very difficult to get a true pin end in a testing machine. It is very difficult to avoid practically pin ended members in a structure. On the other hand, it is in the testing machine almost exclusively that fixed-ended members exist. Some members of a structure are continuous at their ends—held against free deviation of the tangent to their axis by other equally weak (or weaker) members—but about the only example of a fixed-ended compression member is a post abutting squarely on a masonry support. Many compression members are connected to gusset plates at their ends, and the gusset plates are

supposed by some designers to hold the ends of the members perfectly rigid. A gusset plate in a roof truss (for an axis in the plane of the truss), is a better example of a "round end" or "pin end" in a member than a pin, since it allows almost unhindered deviation of the tangent to the axis of the member by bending the plate. Yet such members are considered by designers as being fixed-ended.

An intensely practical feature of column design that exhibited itself (by its absence) in the Quebec bridge wreck, and was totally ignored by the investigating commission, is the absolute need of strong lattice systems, in planes normal to the axis of the bridge, in the vertical posts beside the roadway, where swaying shears exist. When the great traveler fell over to the right and pulled this bridge down (as the investigating commission *did not report*), the whole top system was readily pushed to the right, since the lattice in all the verticals was so flimsy. The verticals crumpled in S shape. A little lateral stiffness in the posts might have broken the traveler in place of the bridge.

Investigators have erred in failing to appreciate the fact that there are two distinct phases to the strength of a column. One has to do solely with the modulus of elasticity and is totally independent of the elastic limit or ultimate strength of the material. It has application to slender columns. The column fails as a spring or bow at the first measurable deflection, and all grades of steel from the softest to the hardest will fail at the same load (the Euler load), since their moduli of elasticity are practically the same. Even imperfect columns, with a very considerable initial bow will have the same strength as perfect ones, and this ultimate strength can be very closely calculated. These are some of the anomalies on the subject.

The Euler formula has little practical use in structural design, because slender columns are tabooed by specifications. In one way, however, it has a bearing on specifications that have to do with nickel steel. Formulae for the strength of soft steel and nickel steel should converge to practically the same value in high ratios of slenderness. This is not the case in some recent specifications.

In spite of the inapplicability of the Euler formula to other than slender columns, this formula is commonly used by European engineers for columns that are not slender. There is no excuse for this.

The other phase of the strength of columns has to do with the crushing strength of the metal or its elastic strength. It has application to short columns. The Gordon-Rankine formula comes near meeting the requirements of this class of columns, but it has two faults or qualities that are apt to give rise to faults or errors. One is that the values do not fall away sufficiently rapid at the start. Very short columns do not have strengths comparable with short blocks or cubes. This may be due to wrinkling of the metal. It

is a fact just the same that needs expression in a practical column formula. The other fault is that unless the constant is such as to keep the load for slender columns below the Euler load, the formula is useless and misleading for long columns. The straight-line formula avoids both these faults and is therefore better suited to practical use.

Dr. W. E. Lilly (Trinity College, Dublin) wrote that he had with pleasure read Professor Basquin's paper on columns, the preparation of which must have involved a large amount of labor. Before proceeding to offer any criticism on it, it would be better, perhaps, to state briefly his own views as to the way in which he considered the subject of columns should be approached; their divergence from those of the author would then become more clearly defined.

Consider a solid column, as shown in Fig. 27, on which the load is applied at a given eccentricity E , let the loading be gradually applied to the column; it then commences to bend or deflect and the magnitude of the deflection depends upon the elasticity of the material, other quantities being assumed constant. As the loading increases the deflection increases, and when it reaches a limiting value, depending on the strength of the material, failure of the

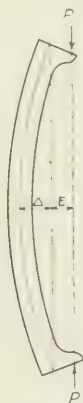


Fig. 27.

column takes place. The problem so considered shows that among other quantities three are involved,—namely the coefficient of elasticity E , the strength of the material F , and the deflection Δ of the column when failure takes place. It follows, then, that any column formula must of necessity among other quantities include these three. The mathematical treatment of the problem is so full of difficulties as to be almost incapable of rigorous solution, notwithstanding the efforts made in this direction by various investigators.

In *Engineering*, of July 2, 1909, January 14, 1910, and March 31, 1911, Dr. Lilly stated his objections to the Eulerian form of analysis as given in Equation 3 of the author's paper, and more recently in a paper published in the *Proceedings of the American Society of Civil Engineers*, vol. XXXVIII, 1912, he had given a list of papers which contained an account of his own experimental work and views on the subject. Briefly he advocated the use of the Rankine-Gordon-Tredgold formula for the design of solid columns, together with his own modification of it when secondary flexure requires to be taken into consideration, for the following reasons: The simplicity of its form, which must always recommend it to engineers. It gives the first approximation as derived from theory. For long columns, experiments show it is nearly correct; for columns of medium length, which comprise the majority of columns in practice, it gives values somewhat less than the experimental values, an error on the side of safety; also, when it is remembered that the effects of eccentricity of loading are most marked in columns of medium length, it is desirable that the formula mostly used should err on the safe side. For short columns it is nearly correct, although the value of the strength to compression is taken greater than that of the yield-point of the material, because experiment shows the strength to compression of short columns always rises above this value. It gives a method by which the shear stresses in a column can be evaluated and thus determine the bracing or web in compound columns.

Reverting now to the paper, the author is to be congratulated for his attempt to bring the observed experimental deflections on columns into line with those obtained from theoretical reasoning, and the results as shown in the various diagrams were of exceptional interest. If it were possible to obtain some empirical function, or discover some law which governs the deflection of columns under load in terms of their dimensions, the evolution of a satisfactory formula for the design of columns would be an easy matter. Unfortunately, owing to the limited range of the slenderness ratio of the experiments on columns, any such generalization was not at present possible. From his own experiments and work, Dr. Lilly was of the opinion that the law or function if discovered would be of a complex form, and before any practical use could be made of it would require to be simplified by taking first approximations. Dr. Lilly had already remarked on the limited range of the slenderness ratio in the experiments on columns in his paper before the American Society of Civil Engineers, and in it had analyzed some almost exactly similar columns to those referred to in the author's paper. He considered it probable that the low values of the coefficient of elasticity in the testing of built-up columns recorded in the paper was due partly to the effect of secondary flexure not being sufficiently allowed for. The curve formation commenced at loads far

below the failing load, and although difficult to measure it required to be considered in addition to the errors of fabrication.

While agreeing with the author in his remarks regarding the rational design of columns, Dr. Lilly was of the opinion that in the present state of our knowledge the Rankine-Gordon formula was the best and safest to be used for the tentative design of columns. He had shown that it could be modified to include all cases of loading likely to arise in practice, a merit so far as he was aware not possessed by any other column formula.

F. O. Dufour (U. of I.): There is shown in this paper some of the results of tensile tests by Mr. James E. Howard on samples of plates and angles. These results indicate that the modulus of elasticity varies from 23,440,000 to 36,860,000 lb. per sq. in. These values illustrate fairly well the results which may be obtained when measurements are taken at one place on a specimen, but whether or not they represent the modulus of elasticity is open to serious doubt.

Inspecting and testing engineers recognize the fact that local-

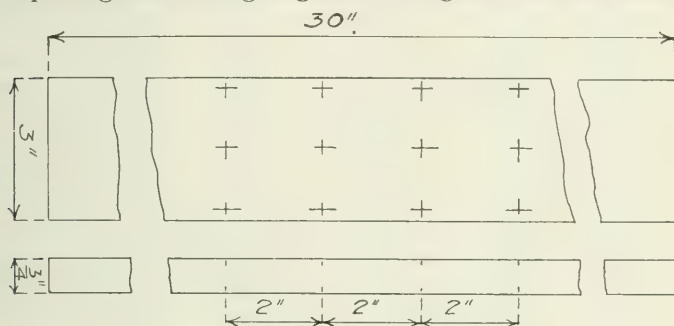


Fig. 28.

ized strains often occur in members; and that these strains may be greater or less than the average. These localized strains are not desirable, yet they are not dangerous as long as the average stresses stay within the elastic limit; and indeed tests indicate that there are cases where the material is locally distributed beyond the elastic limit, while the safety of the entire member itself is not materially endangered. This condition is, of course, made possible by the use of the factor of safety. These localized strains cannot be overcome by any method yet devised.

Table I is compiled from tests made in the Laboratory of Applied Mechanics of the University of Illinois, under the writer's direction by Raymond Roark, a graduate student in Civil Engineering, being a part of his thesis for the master's degree.

The tests were compressive and were made on pieces of steel $\frac{3}{4}$ in. by 3 in. in cross-section and 30 in. long. These specimens were so clamped in the machine that the ends were practically fixed and left a sufficient length to allow a 14 in. gauge length to

be measured off in 2-in. divisions. Measurements were taken over 2-in. gauge lengths on each 3-in. face, at the middle of the specimen, and $\frac{1}{4}$ in. from each edge. A Berry extensometer was used. This instrument reads directly to 0.0002 in. The values used in the table are thought to be correct to within 300,000 lb. per sq. in. Figure 28 shows the location of the 2-in. gauge lengths and also the dimensions of the specimen. The ultimate strength of the specimen was 29,800 lb. per sq. in.

VARIATION IN COEFFICIENT OF ELASTICITY.

Line	1	2	3	4	5	6	7	8	9	10
	Unit Stress, in lb. per sq. in.	E, in million lb. per sq. in. Front and back left hand	E Average	E, in million lb. per sq. in. Front and back center	E Average	E, in million lb. per sq. in. Front and back right hand	E Average	E Average of cols. 3-5-7	E Average of cols. 3 and 7	
1.....	10,000	23.00		21.90		25.10				Upper 2 in. of length
2.....	.....	23.30	32.80	38.20	30.5	32.80	28.95	31.42	30.78	
3.....	15,000	30.00	.....	27.80	.....	25.80	.....	.....	.....	
4.....	.....	28.60	29.30	35.30	31.55	34.1	29.95	30.27	29.63	
5.....	19,000	29.25	.....	27.25	.....	26.20	.....	.....	.....	
6.....	.....	25.30	27.28	25.40	26.30	31.70	28.95	28.18	28.12	
7.....	23,000	25.60	.....	27.10	.....	23.00	.....	.....	.....	
8.....	.....	25.60	25.60	28.90	28.00	28.8	25.90	26.50	25.75	
9.....	26,750	25.40	.....	27.30	.....	21.55	.....	.....	.....	
10.....	.....	22.20	23.80	24.30	25.80	25.00	23.18	24.26	23.49	
a—Col. 8 average of lines 2, 4, 6 and 8								29.09		Middle 2 in. of length
11.....	10,000	28.55	.....	28.55	.....	26.25	.....	.....	.....	
12.....	.....	35.00	31.78	28.55	28.55	30.00	28.13	29.49	29.96	
13.....	15,000	33.20	.....	30.65	.....	26.30	.....	.....	.....	
14.....	.....	37.60	35.40	31.25	30.95	30.00	28.15	31.50	31.78	
15.....	19,000	29.30	.....	28.20	.....	26.10	.....	.....	.....	
16.....	.....	30.60	29.95	27.25	27.63	30.40	28.40	28.66	29.18	
17.....	23,000	30.65	.....	26.40	.....	27.00	.....	.....	.....	
18.....	.....	28.75	29.70	25.55	25.98	28.80	27.90	27.86	28.80	
19.....	26,750	31.50	.....	26.00	.....	24.30	.....	.....	.....	
20.....		20.50	26.00	22.20	24.10	24.30	24.30	24.80	25.15	Lower 2 in. of length
b—Col. 8 average of lines 12, 14, 16, 18	.....	.....	.....	.....	.....	.....	.....	29.38	.....	
21.....	10,000	23.80	.....	24.70	.....	25.00	.....	.....	.....	
22.....	.....	32.30	28.05	26.25	25.43	32.30	28.65	27.71	28.35	
23.....	15,000	28.90	.....	28.60	.....	25.00	.....	.....	.....	
24.....	.....	28.60	28.75	26.35	27.48	30.00	27.50	27.91	28.13	
25.....	19,000	33.40	.....	29.60	.....	23.75	.....	.....	.....	
26.....	.....	23.80	28.60	23.80	26.70	27.10	25.43	28.58	27.02	
27.....	23,000	32.90	.....	29.10	.....	23.00	.....	.....	.....	
28.....	.....	21.90	27.40	27.60	28.35	25.60	24.30	26.68	25.85	
29.....	26,750	33.60	.....	32.40	.....	21.70	.....	.....	.....	
30.....		18.40	26.50	20.50	26.45	24.30	23.00	25.32	25.91	
c—Col. 8 average of line 22, 24, 26, 28	.....	.....	.....	.....	.....	.....	.....	27.72	.....	
Average of lines a, b and c, col. 8								28.73		

Specimens failed at 29,800 lbs. per sq. in.

Values in the table indicate that:

1. The average value of E is almost the same up to a unit stress of 23,000 lb. per sq. in. These results, as well as those of Professor Basquin's, indicate that the ultimate strength of a column lies close to the elastic limit of the material, being practically the same.

2. The computed values of E vary not only across the section and longitudinally on one side, but on both sides.

3. The variation is from 21,900,000 to 38,200,000 lb. per sq. in., which is greater than that reported by Howard.

4. While the variation is large in some cases where the gauge lengths are close together, lines 1 and 2, Col. 4, where the values are 21,900,000 and 38,200,000, the average is close to the means of all the values.

5. The mean value of the modulus of elasticity is 28,730,000 lb. per sq. in. This appears to be about the value usually considered correct—29,000,000 to 30,000,000 as stated by Prof. Basquin.

The above indications appear to show that Buchanan's results were computed from readings taken from an extensometer in one position only. Also that great variation in stress from variation of the modulus of elasticity is unlikely.

Other tests by Mr. Roark indicate that rivets do not completely fill the holes in compression members and consequently gauge lengths over rivets not only record the distortion of the metal itself, but the movement necessary to allow it to come to a bearing. This shows that determination of stress or modulus of elasticity from extensometer measurements over gauge lengths containing rivets are not reliable indications of the actual condition. This is mentioned indirectly by Professor Basquin in the second paragraph, on the second page of his paper. However, the gauge length should not only be located so as to exclude the pin plates, but it should not include any rivets.

In order to ascertain to what extent the design of columns as suggested by Professor Basquin would differ from the design by methods in common use, two columns were taken and the maximum unit stress curves plotted from results obtained from the formulae:

$$(2) \quad S = \frac{P}{A} + \frac{Pec}{I_{a-a} - \frac{P^2}{KE}} + \frac{Pe'c'}{I_{b-b} - \frac{P^2}{KE}}$$

$$(3) \quad S = \frac{P}{A} + \frac{kl}{r} + \frac{Mc}{I}$$

The value of K was taken as 10, being the one commonly used for members free at the ends. In case of columns having an intentional eccentricity, no eccentricity (c') was assumed about the other axis. In cases where no intentional eccentricity was present, c was taken equal to c' and assumed equal to 1/16 in. for each 5 ft. in length. In formula (3) k is taken as 70, this being the value used in the American Railway Engineering Association's

formula. The value $\frac{kl}{r}$ represents the stress at the center due to column action alone, $\frac{Mc}{I}$ represents the stress due to the exterior moment.

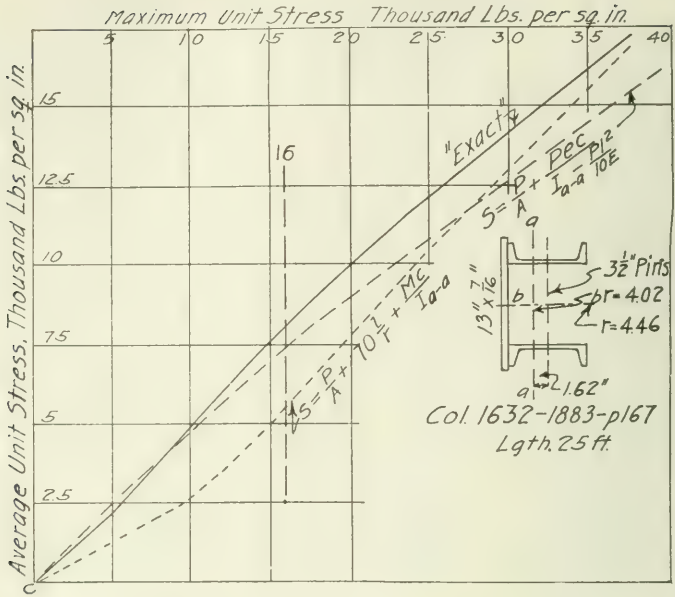


Fig. 29.

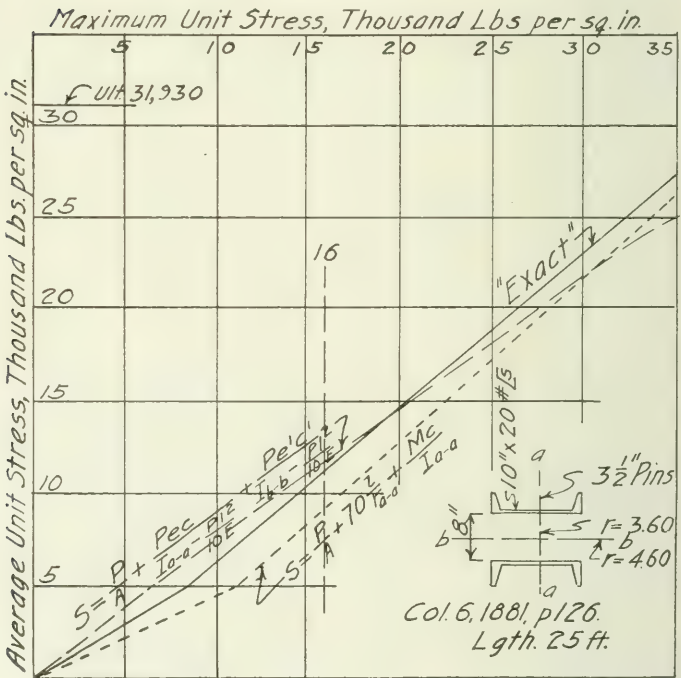


Fig. 30.

Column 1632-1883, p. 167 (Fig. 29), is what may be called a normal column. Its greatest deflection is perpendicular to the pins. Column 6, 1881, p. 126 (Fig. 30), is what may be called an abnormal column, since the greatest deflection is parallel to the pin.

Column design is based upon the assumption that the maximum stress shall not exceed a certain amount,—16,000 lb. per sq. in. according to the American Railway Engineering Association specifications. A vertical line representing the 16,000 lb. limit is drawn in Figs. 29 and 30. The abscissa from the point where it intersects the lines of the several formulae plotted, intersects the ordinate to the left representing the unit load which may be allowed on the column, i. e., the unit load used in designing the member. Table II gives the results, the formula involving the Eulerian secant being called the "exact formula" for convenience of reference.

TABLE II. COMPARATIVE ALLOWABLE UNIT LOADS.

All Values Are in Pounds Per Square Inch.

No.	Formula.	Col. 1632-1883	Col. 6-1881
		$c = 1.50''$ $e' = 0''$	$c = 5/16''$ $e' = 5/16''$
1.	"Exact"	8,000	11,500
2.	$\frac{P}{A} + \frac{Pec}{P l^2} + \frac{P e' c'}{P l^2}$ $I_{aa} - \frac{P l^2}{10 E} \quad I_{bb} + \frac{P l^2}{10 E}$	7,500	11,600
3.	$\frac{P}{A} + 70 \frac{l}{r_{b-b}} + \frac{M c}{I_{b-b}}$	5,500	9,250

An inspection of Figs. 29 and 30 and Table II appears to indicate that

1. For practical purposes formula No. 2 is as reliable as the "exact" formula, since the results differ little.

2. Formula No. 3 gives values on the safe side, apparently much too low in these two cases.

3. The value $70 \frac{l}{r}$ gives too great a value for the bending due to column action only.

In addition to formula No. 2 giving values close to those obtained from the "exact" formula, it is much more convenient to use. The results of these two column tests appear to show that there is little bending due to column action, and that the "exact" formula more nearly represents the actual facts, since it shows the

column to fail at unit stress equal to which we may reasonably expect to be the value of the yield point of the material.

The point mentioned in regard to assuming an "accidental eccentricity" equal to $1/16$ in. for each five feet in length appears to the writer to be a valuable one; and this amount should be used in practice whenever the "exact" or formula No. 2 is used, but it is inadvisable to allow for accidental eccentricity in the case of the straight line formula, since this gives values sufficiently low to be safe without such allowances. Many years of experience by the writer in inspection indicates that the allowance mentioned fairly well represents actual conditions of present day practice.

The writer wishes to congratulate the author on this paper. It has brought to our notice many conditions which we have hitherto overlooked in the determination of the stresses in columns; it has shown us the limitations of our commonly used formulas, and has widened our horizon to the possibilities of more intelligent design.

Mr. Basquin: STRAINS OF FABRICATION.

Templet makers commonly allow $1/32$ in. in 6 ft. as the longitudinal extension that takes place in column shapes and plates during the process of fabrication. If we consider a single plate that is to receive two symmetrical rows of rivets, we may imagine that the central portion of the plate will be practically undisturbed by the punching and riveting, except that it will suffer the above mentioned elongation of about 0.045%; hence we may conclude that this portion of the plate, when finished, will have a tensile stress of about 13,000 lb. per sq. in. The total tensile force over the undisturbed sectional area must equal the total compressive force distributed over the disturbed areas. This leads to the conclusion that there are large compressive stresses distributed along longitudinal lines of rivets in fabricated steel members.

The discussion of shapes is complicated by the fact that in many cases they are straightened after punching, but strains in them due to riveting will give rise to tensile and compressive stresses, distributed somewhat as in plates.

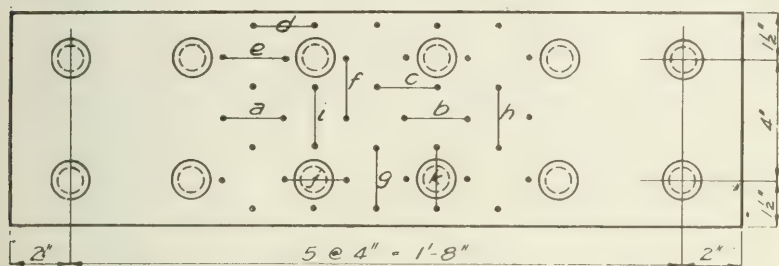
These considerations naturally lead to the suggestion that, in this respect, a column section is to be preferred that does not have rows of rivets at its corners, for it is one of these corners that will certainly receive the greatest unit stress due to the column load. In this connection it may be recalled that the Z-bar columns tested by C. L. Strobel^{*39} showed unusually high elastic ranges of stress, and that they had no rivets along the projecting flanges except at their ends.

Two tests upon the strains of fabrication have been made with the coöperation of Mr. J. G. Kreer, President of the Chicago Steel Products Co.

First Test. The first test plate was prepared as shown in Fig.

* 39. Trans. Am. Soc. C. E. Vol. 18, p. 103, 1888.

31. The small black circles show the ends of gauge lines, each 2 in. long. The gauge lines may be divided into groups according to their positions with respect to the rivets, and one line of each group is given a letter, *a, b, c*, etc., each of which letters is understood as belonging to the whole group of lines that have a common relation to the rivet holes. The punching was done with an ordinary machine punch, operated by a man skilled in that work, and



One 1/2" Plate, 3/4" Rivets, 1 3/16" Punch, 5/8" Die

Fig. 31.

is thought to represent ordinary practice. The strains were measured by means of a Berry strain gauge, and were referred to a reference line laid off on a small strip of steel cut from the test plate.

The strains due to punching are shown in the following table. Strains of elongation are regarded as positive, contraction as negative. The "front" side of the plate is that on which the punch entered.

UNIT STRAINS DUE TO PUNCHING EXPRESSED IN PER CENT.

Gauge Line	Front	Back	Mean
<i>a</i>	0.00	+0.02	+0.01
<i>b</i>	−0.03	+0.06	+0.02
<i>c</i>	−0.02	+0.05	+0.02
<i>d</i>	−0.02	+0.04	+0.01
<i>e</i>	+0.04	−0.09	−0.03
<i>f</i>	−0.01	+0.03	+0.01
<i>g</i>	−0.02	+0.05	+0.01
<i>h</i>	−0.00	+0.02	+0.01
<i>i</i>	+0.02	−0.10	−0.04
<i>j</i>	−0.06	+0.19	+0.06
<i>k</i>	−0.03	+0.19	+0.08

Rivets were machine driven by a man thoroughly skilled in this work; the machine was adjusted to give good pressure and the rivets were well heated. The test differs from standard practice in that the rivets passed through only one plate instead of two or

more. This was necessary, in order to measure the gauge lines on the back of the plate. The plate was slightly bent in punching but was much more bent in riveting, the deflection being about $\frac{3}{16}$ in. in 2 feet. Although the rivets were at a distance of $1\frac{1}{2}$ in. from the edges of the plate, the rivets pushed the edges out so that the plate was about 0.05 in. wider across the rivets than midway between them. The resulting strains, because of the conditions mentioned above, and because of the large number of rivets in comparison with the size of the plate, were found to be excessive and cannot be thought to represent current practice. Strains *k* were too large to measure; strains *j* could not be measured because rivet heads were in the way, and negligence in taking initial readings made it impossible to determine whether strains *i* were small extensions or large contractions. The remaining strains were found to be as follows:

UNIT STRAINS DUE TO RIVETING EXPRESSED
IN PER CENT.

Gauge Line	Front	Back	Mean
<i>a</i>	+0.02	+0.05	+0.04
<i>b</i>	+0.44	+0.47	+0.45
<i>c</i>	+0.22	+0.31	+0.26
<i>d</i>	+0.23	+0.31	+0.27
<i>e</i>	-0.18	-0.33	-0.26
<i>f</i>	+0.10	+0.07	+0.09
<i>g</i>	+0.01	+0.01	+0.01
<i>h</i>	-0.00	-0.04	-0.02

The shoulders of the rivet heads on one side of the plate were cut off, using a hollow drill (lathe mill) and the rivets were driven out. The force on the rivet heads had been so great as to form distinct depressions in the plate, the depth of which varied up to a maximum of about 0.015 in. After remeasuring the gauge lines, the rivet holes were bored out to a diameter of $1\frac{3}{4}$ in. The average strains found for each of these changes are as follows:

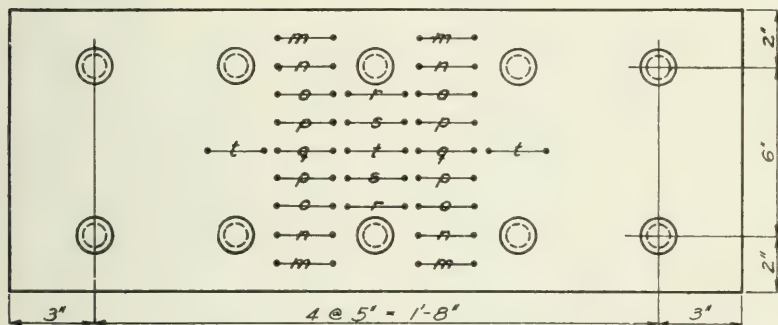
AVERAGE UNIT STRAINS EXPRESSED IN PER CENT

Gauge Line	Found After Removal of Rivets	Found After Enlargement of Holes
<i>a</i>	+0.009	-0.007
<i>b</i>	+0.005	+0.008
<i>c</i>	+0.007	-0.005
<i>d</i>	+0.007	-0.002
<i>e</i>	+0.002	-0.032
<i>f</i>	+0.011	+0.005
<i>g</i>	+0.009	-0.002
<i>h</i>	+0.015	-0.006
<i>i</i>	+0.007	-0.042

The last decimal place shown in these results is probably of little significance. The reason for a nearly uniform extension of the plate of about 0.01% upon the removal of the rivets is not understood and may be due to some error. The result that is particularly striking is that gauge lines *c* and *i* contracted very markedly on the enlargement of the rivet holes, whereas one might naturally expect them to extend. This matter is referred to below.

Second Test. It was felt that information which would be more directly serviceable might be obtained from the use of two plates riveted together than from a single plate. It was thought wise, also, to use a smaller number of rivets in proportion to the size of the plates than was used in the first test and to use a smaller force in driving the rivets. Two select plates of open hearth steel were prepared with 2 in. gauge lines as shown in Fig. 32.

Before punching, the plates were nearly flat surfaces. For the initial measurement of gauge lines the plates were clamped to-



Two $\frac{1}{2}$ " Plates, $\frac{3}{4}$ " Rivets, $\frac{1}{16}$ " Punch, $\frac{7}{8}$ " Die.

Fig. 32.

gether by means of *C* clamps. This was done in order that the observed strains might not include effects due to a bending of either plate as a whole. For the same reason the plates were well bolted together after punching and before taking measurements of gauge lines for punching strains. The punch entered the plates on the faces that were later placed in contact in riveting. The observed strains due to punching and riveting were found as shown in the following table, extension being regarded as positive.

OBSERVED UNIT STRAINS DUE TO PUNCHING,
EXPRESSED IN PER CENT.

Gauge Line	Plate A	Plate B	Mean
<i>m</i>	—0.001	—0.009	—0.005
<i>n</i>	—0.003	—0.013	—0.008

<i>o</i>	—0.007	—0.009	—0.008
<i>p</i>	—0.005	—0.001	—0.003
<i>q</i>	—0.005	+0.001	—0.002
<i>r</i>	+0.006	+0.006	+0.016
<i>s</i>	—0.003	+0.007	+0.002
<i>t</i>	0.000	+0.008	+0.004

OBSERVED UNIT STRAINS DUE TO RIVETING
EXPRESSED IN PER CENT.

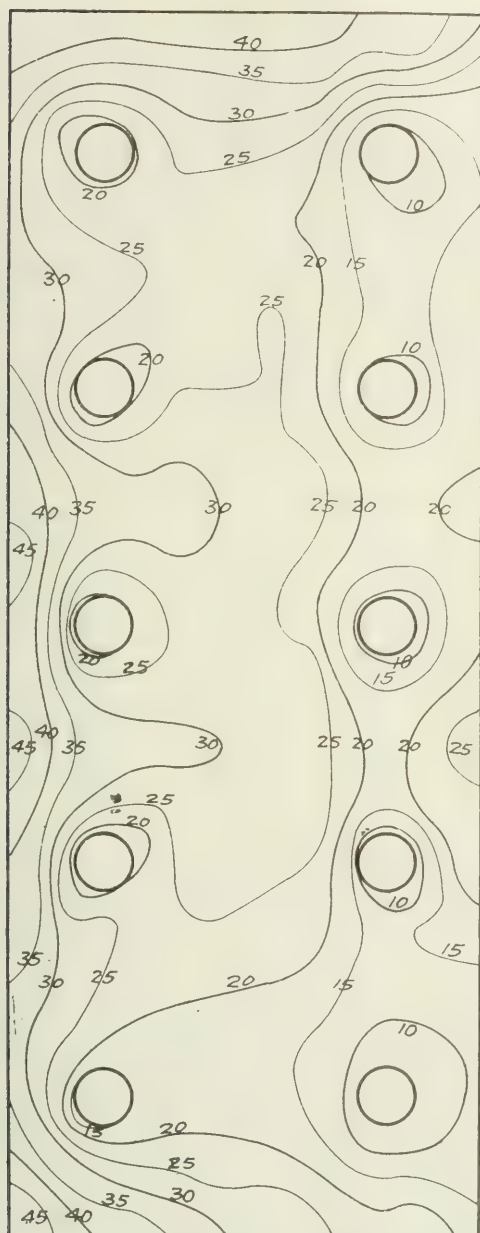
Gauge Line	Plate A	Plate B	Mean
<i>m</i>	+0.063	+0.046	+0.055
<i>n</i>	+0.006	0.000	+0.003
<i>o</i>	+0.022	+0.028	+0.025
<i>p</i>	+0.025	+0.031	+0.028
<i>q</i>	+0.032	+0.038	+0.035
<i>r</i>	+0.003	+0.065	+0.034
<i>s</i>	+0.014	+0.062	+0.038
<i>t</i>	+0.020	+0.045	+0.033

The strains due to punching are proportioned over the plate about as one might expect, and the strains of the individual gauge lines of each group show a satisfactory regularity.

In drawing conclusions from the observed strains due to riveting, we must remember that we have two plates riveted together, and that the gauge lines are on the exposed faces of the plates. Bach and Baumann^{*40} have called attention to the useless and injurious effects of using a very large force applied to a rivet in the process of driving it. They found the tensile stress in the stem of practically all rivets to be about 30,000 lb. per sq. in., irrespective of the force used in driving them. A large force used in driving rivets tends to crush the plates.

The force applied in driving the rivets of this test was roughly estimated as 40 tons, and according to usual standards the riveting is believed to be of first-class workmanship. For the purpose of showing more clearly some of the effects of riveting, the surface of the plates was cleaned of scale and the thickness of the combined plates was measured at numerous points. The contour lines of thickness shown in Fig. 33 have been drawn to illustrate the variation of thickness thus obtained. It is at once evident that the rivets have caused dimples in the plates. These have been formed because the plates are elastic; the portions of a plate under a rivet head are forced together and compressed by the pressure on the rivet heads; the area of bearing between the plates is enlarged on account of the compression, and as the area of bearing between the plates becomes larger than that of a rivet head, there are intro-

* 40. Zeitschrift des Vereines deutscher Ingenieure, Vol. 56, No. 47, p. 1890, Nov. 23, 1912. Reprints may be had at a cost of 85 pf. Their conclusions are given in Journal Am. Soc. M. E., Feb. 1913, p. 339.



CONTOUR LINES OF THICKNESS
2 PLATES RIVETED TOGETHER

Numbers indicate thickness in excess
of one inch, expressed in thousandths.

duced into the plates bending moments, which act in planes passing through the axis of the rivet.

Another set of measurements was made upon the thickness of the combined plates, a reading being taken at the center of each gauge line as well as at each end. The excess of the center reading over the mean of the end readings gives double the deflection of each plate in a length of 2 in. Thus knowing the deflection and assuming constant curvature, we find that the unit strain at the surface due to this bending is numerically equal to half the deflection expressed in inches. The observed strains are the actual unit strains at the exposed surface of the plates. At the mid-thickness of each plate, i. e., $\frac{1}{4}$ in. from the surface, the unit strains will be the observed strains minus the strains due to bending. On the two faces that are in contact the strains will be the observed strains minus double the strains due to bending. The strains shown in the following table have been estimated in this manner:

Gauge Line	Excess Thickness At Center. Inches	UNIT STRAINS DUE TO RIVET- ING EXPRESSED IN PER CENT		
		At Exposed Surface Observed	At Mid-Thickness Bending	of Each Plate
<i>m</i>	+0.0037	+0.055	+0.09	—0.04
<i>n</i>	+0.0033	+0.003	+0.08	—0.08
<i>o</i>	+0.0020	+0.025	+0.05	—0.03
<i>p</i>	+0.0015	+0.028	+0.04	—0.01
<i>q</i>	+0.0008	+0.035	+0.02	+0.01
<i>r</i>	—0.0036	+0.034	—0.09	+0.12
<i>s</i>	—0.0007	+0.038	—0.02	+0.06
<i>t</i>	0.0000	+0.033	0.00	+0.03

While the numerals in the fourth decimal place in the values for the excess thickness are not reliable, it is thought that the values given for the bending strain are very nearly correct since the first set of numbers is divided by 4 in obtaining the latter.

In Fig. 34 two base lines are shown; the lower one passes through the centers of gauge lines *m*, *n*, *o*, *p*, and *q* of Fig. 32, the upper one through the centers of *r*, *s*, and *t*. At right angles to these base lines, distances have been laid off proportional to the strains of the various gauge lines. Strains of extension are shown above the base lines, contraction below. The height of the shaded area at any point of a base line shows the unit strain at that point due to riveting, not the observed strain at the surface, but that derived for the mid-thickness of each plate and given in the last column of the above table. The dotted lines in Fig. 34 refer to the observed strains due to punching. They are drawn in the same way as those for riveting but the scale used in plotting them is ten times that used in plotting the strains due to riveting. The strains due to riveting are about eight times those due to punching. At a point on the center line of the plate and on a transverse line con-

necting two rivets (the upper base line of Fig. 34), the strains indicate a tensile stress of about 10,000 lb. per sq. in. due to fabrication. Near the rivets the strains on the same base line indicate that, in the riveting, the stresses passed the elastic limit of the material. This does not mean that a tensile stress equal to the elastic

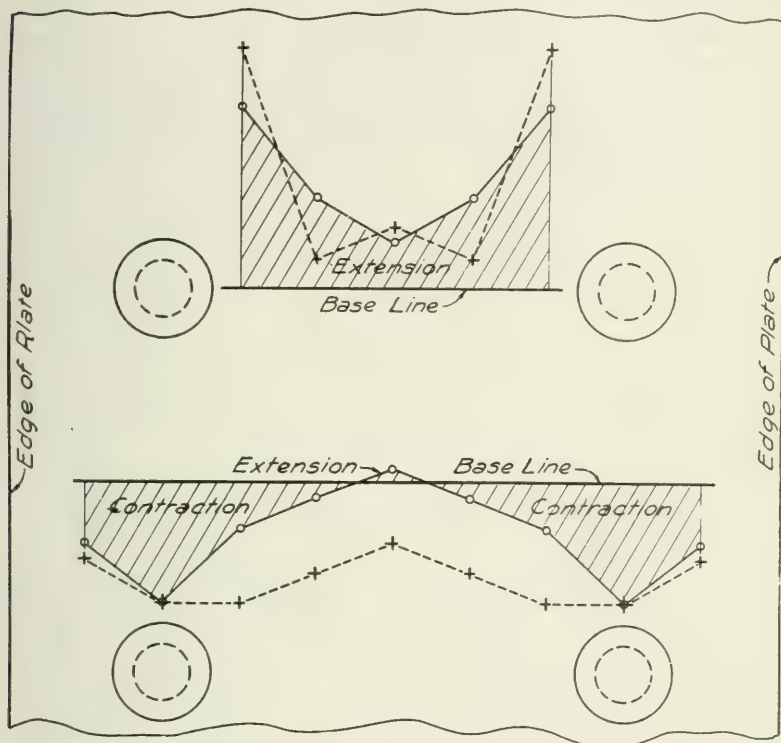


DIAGRAM SHOWING DISTRIBUTION OF STRAINS OF FABRICATION
IN DIFFERENT PARTS OF A RIVETED PLATE

Fig. 34.

limit remains in those parts after the rivets are driven. On the contrary, we have the apparent paradox that compressive stresses are likely to be found wherever the extensions indicate tensile stresses beyond the elastic limit.

In order to make this clear, let us consider the whole transverse section on the upper base line. The sum of the forces acting across the section must be zero, i. e., the sum of the tensile stresses must equal the sum of the compressive stresses. Though all the gauge lines show extension, there must be compression in some part. There is surely tension along the center line of the plate, since the extension there indicates a stress of only about 10,000 lb. per sq.

in. But near the rivets the material was forced by the temporary lateral pressure of the riveting machine to extend beyond its yield point, and this extension caused the smaller extensions in parts farther removed from the rivets. When the pressure from the riveting machine was removed, the material under its immediate action would tend to return to its former proportions. But when this material reached its new natural dimensions, there were still tensile stresses in adjoining parts, and hence the material near the rivets was caused to contract still farther and to take compressive stresses, until the sum of the compressive stresses, thus introduced, was just equal to the sum of the tensile stresses remaining in other parts of the section.

If we consider the strains along the lower base line of Fig. 34, we may interpret them in a manner that is somewhat analogous. The strain is a maximum at gauge line *n*, Fig. 32, located on the longitudinal line of rivets, and the stress indicated is about 27,000 lb. per sq. in. But the strains along the whole base line indicate a preponderance of compressive stress which is impossible. Hence we may assume that gauge line *n* was stressed in the process of riveting slightly beyond its elastic limit in compression, and that its recovery, together with the extension caused in it by the action of adjoining parts of the plate, have been sufficient to reduce its strain to about -0.00% . So that, although the strain indicates a compressive stress there is really a tensile stress along this particular gauge line.

If this view is correct, it may throw some light upon the unexpected contraction of gauge lines *c* and *i*, which took place when the rivet holes of the first plate were enlarged. However, the plate used in that test was so severely strained in all parts by the riveting, and the gauge lines were so poorly arranged, that it seems impossible to apply this reasoning to it with any certainty.

The tests confirm, in a general way, the conclusion of the first paragraph; namely, that there are large compressive stresses distributed along the lines of rivets of fabricated steel members. It has not been possible in these tests to determine the magnitude of these stresses, because where the strains are large, the corresponding stresses are probably not proportional to the strains. It may be noted also that a gauge line of 2 in. is too long to use for the careful investigation of stresses which are distributed in such an irregular manner as are those in riveted work.

Do stresses of fabrication disappear with time in a manner similar to the recovery of steel when over-strained? Recovery from over-strain is usually studied in specimens that have suffered an approximately uniform over-strain in all parts, such as a tensile specimen. Stresses of fabrication differ from this in that stresses that oppose each other are set up in different parts of a cross-section. It is hard to see how such stresses can be relieved by lapse of time. Glass and cast iron are very much more subject to time

effects than steel, and we know that strains in such materials suffer little relief with time—they are removed by annealing.

The stresses accompanying straightening seem to be of the same nature. If a bar is bent until the stresses in its extreme fibres have passed the elastic limit, these extreme fibres will, when the bar is released, take stresses of the opposite kind from those which they had when bent; while the fibres near the gravity axis will have stresses of the same kind as they had when bent. Recovery from over-strain doubtless applies to that material of the bar that has been over-strained; i. e., the outer fibres recover their former properties, but that does not imply that the internal stresses of the bar have disappeared.

COLUMN FORMULAE.

The reasonableness of column formulae may be discussed from the standpoint of eccentric loads. For illustration, let us take the following formulae:

Philadelphia:

$$p_o = \frac{12,250}{1 + \frac{l^2}{11,000 r^2}}$$

New York:

$$p_o = 15,200 - 58 \frac{l}{r}, \quad \frac{l}{r} = 0 \text{ to } 120$$

American Railway Engineering Association:

$$p_o = 16,000 - 70 \frac{l}{r}, \quad \text{with 14,000 as maximum.}$$

American Bridge Co.:

$$p_o = \begin{cases} 13,000 & \frac{l}{r} = 0 \text{ to } 60 \\ 19,000 - 100 \frac{l}{r} & \frac{l}{r} = 60 \text{ to } 120 \\ 13,000 - 50 \frac{l}{r} & \frac{l}{r} = 120 \text{ to } 200, \text{ for secondary members only.} \end{cases}$$

The allowable unit loads given by these formulae are shown plotted in the upper part of Fig. 35.

The expression for the maximum stress, p , in a column whose eccentric load is in the plane of least radius of gyration is

$$p = p_o \left(1 + \frac{ec}{r^2} \sec. \theta \right). \quad \text{Let us assume that when the load is}$$

doubled the maximum stress becomes 30,000 lb. per sq. in. With this assumption the above expression becomes

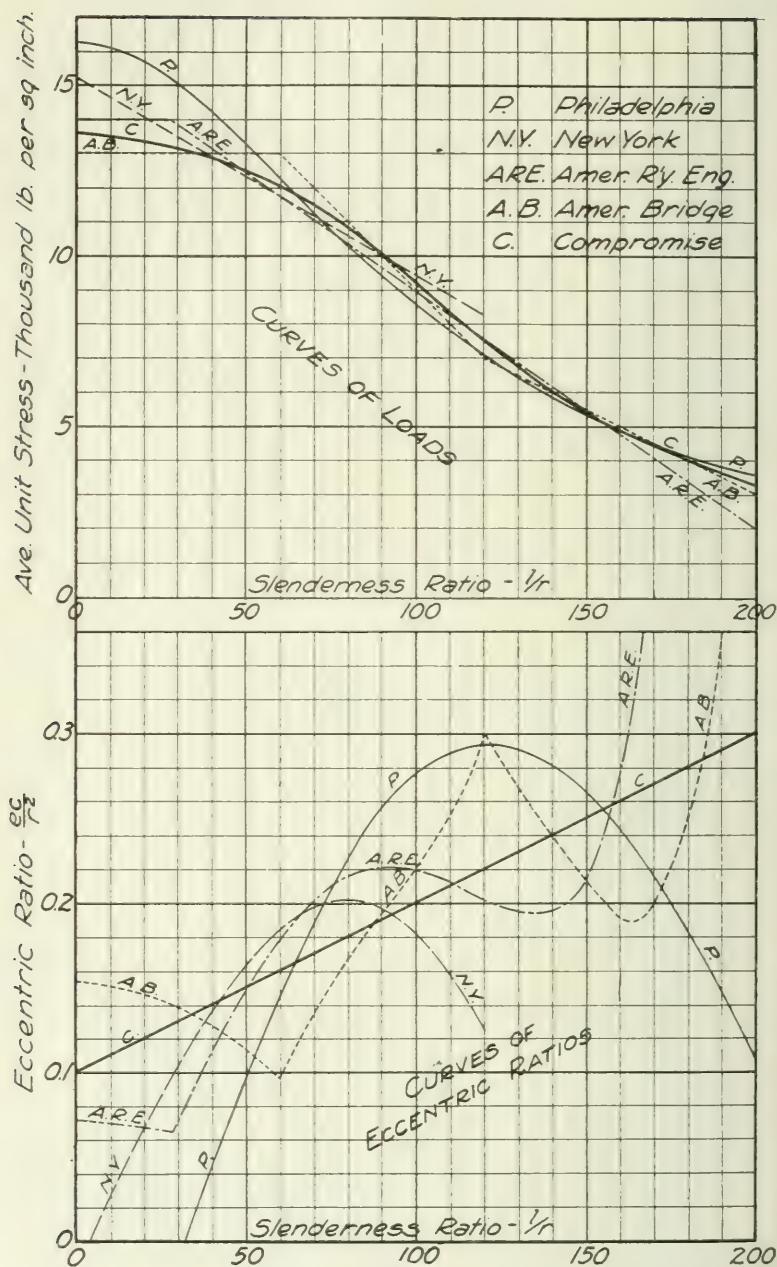


Fig. 35.

$$30,000 = 2 p_o \left(1 + \frac{ec}{r^2} \sec \theta \right)$$

which may be written in the form

$$\frac{ec}{r^2} = \left(\frac{15,000}{p_o} - 1 \right) \cos \theta$$

Each column formula defines p_o for every value of $\frac{l}{r}$, hence

the eccentric ratio $\frac{ec}{r^2}$, tacitly assumed in any column formula, may be readily calculated for any value of $\frac{l}{r}$. This has been done for

the above formulas and the results are shown plotted in the lower part of Fig 35. The eccentric ratios are seen to vary in a rather erratic manner. If we had taken a factor of safety other than 2, or a maximum stress other than 30,000, we should have obtained different values for the eccentric ratios, but the general character of the curves would have been similar to those shown.

In the lower part of Fig. 35 a straight line has been drawn whose equation is

$$\frac{ec}{r^2} = 0.1 + 0.001 \frac{l}{r}.$$

It seems to represent fairly well an average value of the eccentric ratios obtained from the above column formulas, and hence we may call it a compromise, after Waddell. From the eccentric ratios given by this line or equation one may calculate the corresponding

allowable unit loads for various values of $\frac{l}{r}$ and obtain the following:

$\frac{l}{r}$	Compromise Unit Load	$\frac{l}{r}$	Compromise Unit Load
0	13,650	100	9,200
10	13,500	110	8,325
20	13,325	120	7,485
30	13,110	130	6,700
40	12,825	140	6,000
50	12,500	150	5,380
60	12,050	160	4,830
70	11,500	170	4,350
80	10,835	180	3,947
90	10,045	190	3,589
		200	3,270

A curve corresponding to these unit loads has been drawn in the upper part of Fig. 35. There are only three points in which it is the highest or lowest curve, viz., at slenderness ratios 35, 90, and 155, and at each of these points it is very close to two other curves. While it is quite possible that these compromise loads represent standard American practice better than those given by any single column formula, the object in giving them is not to advocate their use, but rather to illustrate a method of obtaining such loads which correspond to certain definite assumptions regarding factor of safety and eccentric ratio.

As pointed out in the paper, the maximum stress is a function of the eccentricity in the plane of greatest as well as that of least radius of gyration. And it is quite probable that allowable loads should be estimated on a basis of the *mean* slenderness ratio together with the sum of the eccentric ratios in the two planes.

BOOKS.

Two books dealing with the subject of columns are of recent publication and deserve attention. Cyrus A. Melick, in *Stresses in Tall Buildings*, compares the stresses of a tall building as obtained in the ordinary way with those obtained from an analysis much less approximate; reports are included of strain variation in two columns and of building deflection under wind pressure. W. Alexander, in *Columns and Struts*, gives an elaborate and careful discussion of columns from a thoroughly modern point of view. The former book is published by the Ohio State University, the latter by Spon & Chamberlain.

ORAL DISCUSSION BY MESSRS. I. F. STERN, C. B. LEWIS, JOHN F. HAYFORD, F. E. DAVIDSON, P. W. LEISNER, F. G. VENT, AND O. H. BASQUIN, PRESENTED APRIL 14, 1913.

I. F. Stern, M. W. S. E. (Chairman): The matter that impressed me most, in reading the paper and in listening to Professor Basquin, is the fact that with the data on hand one can draw valuable conclusions. With the amount of experimenting that is being done upon columns, we certainly can expect some very practical results, if the data are handled in as careful and consistent a manner as the present data (some of which are 20 or 25 years old), have been treated by Professor Basquin. It is also gratifying to know that a theory can be formulated which is consistent with experiments thus crudely made.

C. B. Lewis, M. W. S. E.: I have had no opportunity to read the paper carefully, but would like to know if the subject of erection stresses, or, rather, stresses due to imperfections in workmanship entailing untrue erection—if I may use that expression—have been considered in the paper?

Mr. Basquin: So far as I know, the only discussion of that

matter is in the general paper, in which I considered the poor bearings that columns have at their ends.

Mr. Lewis: That is one phase of it. At other times there are quite serious stresses—I have no idea just what the figures would amount to—but there are quite serious stresses brought into columns by the twisting of the plumbing up cables.

Mr. Basquin: I do not think any one has discussed that. The question taken up was the poor bearing in testing machines. In the tests discussed we see certain changes in the deflection occurring at the beginning of the test. The interpretation of this is, there was a poor bearing which caused the column to deflect one way or the other; therefore, making certain assumptions, one can tell in what direction the poor bearing was and the amount of it.

Mr. Lewis: I have seen columns where one tier was put on the other, both columns having milled ends, and yet in the Bentley section column one edge was in good contact and at the other side they were separated as much as $1/16$ or $1/32$ in., and shims were put in.

Mr. Basquin: That matter was gone into somewhat, in the general paper, in which it is shown that if we have a bearing with a given error, we can estimate the stress that will be due to the error, but we must know the error and also the characteristics of the column.

Mr. Stern: In the discussion, this statement is made: "They found the tensile stress in the stem of practically all rivets to be about 30,000 lb. per sq. in., irrespective of the force used in driving them." I will ask Professor Basquin if he knows how the stress was measured in the stem of rivets.

Mr. Basquin: The rivets were driven in pieces of steel plate that were about 4 in. square, and the length of the rivet over all was measured. The steel plate was then cut away, turned out, leaving the rivet intact. They measured the length of the rivet again and found the change in length. That gave them a strain, which when multiplied by the coefficient of elasticity, gave approximately 30,000 lb. per sq. in. for all rivets.

Mr. Stern: Reference is made in the general paper to the stresses in the members due to punching and riveting. Why are not those things taken into account in connection with beams also,—built-up girders?

Mr. Basquin: I do not know that they should not be. I do not know that they should be.

When I suggested that there is already a stress of 13,000 lb. in some part of the column, I did not mean to say that only 3,000 lb. should be put on as load. The object of the tests was to find out what the facts were and we found a stress of about 20,000 lb. per sq. in. I am not at all certain that high stresses of fabrication distributed over small areas render a column unsafe. That is to say, there are certain areas in the column that are initially stressed up

to the yield point, and that is true of all fabricated material and of all material that goes through the straightening process. There are certain portions that have very high stresses, but when the load comes on, other areas take that load until they get up to a high stress; and, the areas having an initial high stress, yield slightly and thus take a portion of the load,—nearly their full proportion of it. All of this is as true of beams as it is of columns.

When I wrote the latter part of my original paper, I tried to suggest a method of column design that is as largely rational as possible, and as I did not know what those fabrication stresses were, I put them in. Now, if it comes out that the fabrication stresses are already up to the elastic limit, we shall have to neglect the fabrication stresses in part. That may not be so bad if the areas of high initial stress are not very large.

It was pointed out here last year, I think, that secondary stresses as such are not so dangerous as a great many other stresses.

Mr. Stern: Along the line of the question I asked with regard to beams, it seems to me that the question that is opened up with regard to fabrication stresses should be more vital with regard to beams than to columns, because we have tensile stresses there entirely, and those are the stresses we have to look out for more than compressive stresses. I do not want to go further into that question, because we might come to the conclusion we would have to start over with our theory of designing.

John F. Hayford, M. W. S. E.: In regard to this question as to whether fabrication stresses are just as serious in the case of a beam or girder as in the case of a column, it seems to me one point ought to be brought out that we have nothing corresponding to the dangers due to eccentricity in the case of a girder. That is to say, it makes no difference, in the case of a girder, particularly, whether the fabrication stress is one thing on one part of the girder and a little less on some other part, but on a column it does. If a much heavier pressure is used in riveting on one part of the column than on the other, then what is virtually an eccentricity is introduced, and the strength of the column is considerably reduced. Therefore, the fabrication stresses tend to be much more serious, I think, in the column than in the other case, because eccentricity in the case of the column is the main danger; that is the thing which controls largely.

Professor Thayer asks, in his discussion, whether the “accidental eccentricities” will not be as often negative as positive. Of course, he had in mind that if they are as often negative as positive we have a compensation of errors, a possible elimination of errors due to eccentricity, just as we have compensation of errors in surveying, for example. It is not simply a question of positive and negative; we have not simply two directions, but many directions, to deal with, and therefore there is much less tendency to compensation.

I think it should also be pointed out that there is another reason why we should expect little compensation. If we are to have compensation, then the eccentricities must occur in the same part of the length of the column. That is, if we have a defect of material, say, on one corner of the column but near the upper end of the column, of course, if we have a corresponding defect right opposite that, on the opposite corner,—at the northwest and southeast corners of the column, let us say,—and at the same point along the length of the column, those might compensate so far as producing eccentricity is concerned. But if we have one at the top of that column and the other half way down, that is, at different points longitudinally, they will not compensate at all. To secure compensation we must have the same defects in the same amount diametrically opposite each other on the cross section and directly opposite longitudinally. Ordinarily we will get little or no compensation of the different eccentricities, so it is far from being the case which Professor Thayer apparently had in mind.

Again, Professor Thayer says, in his discussion: "It would seem as though a great deal of valuable information might be acquired by testing columns machined to be exactly straight, and connected by rivets driven through holes drilled in place." That suggestion belongs in a general class of suggestions in regard to columns to the effect that in testing it is desirable to use a perfect column. Many of the discussions of column formulae are based on the idea that one should deal in theory with the perfect column. Now, I submit that what the perfect column will do is of practically no interest; that if a formula is based upon a perfect column, that is, one having no eccentricities of any kind throughout, that formula is of practically no interest. Suppose we design 100 columns, to be exactly alike, and we build them as nearly alike as we can. The best of those columns will have a strength approaching the strength of the perfect column, but approaching it not very closely. What we are interested in, in those 100 columns, and the thing which is important, is not how strong will the strongest one be (that is of practically no interest for engineering purposes), but which of those columns will be the weakest and how weak will it be. Therefore we ought not in our formulae, and in our discussions, to deal with the perfect column. We ought to deal with the column having important imperfections; imperfections of the same order of size as the imperfections we get in the rolling in cross-section; imperfections in the connecting up of the different parts of the column, and imperfections produced by the fabrication stresses.

We ought not to discuss an ideal column, which gives an upper limit of strength which is of no interest. We ought to deal with the imperfect column; we ought to make our reasoning such as to try to find out how weak the weakest of the 100 columns would be. That is the line along which Professor Basquin has been working. I submit that any discussion which starts out with a column formula,

which is based upon the idea that we should investigate the ideal column which has no imperfections, is of little importance. The important matter to be discussed is, how much do we weaken a column by unavoidable imperfections in manufacture and erection?

F. E. Davidson, M. W. S. E.: Professor Hayford brought out a point which has a great deal to do with this question of the strength of columns. Structural steel, under manufacturers' standard specifications, is permitted to have a variation of $2\frac{1}{2}\%$ plus or minus. For example, suppose we assume a column made up of two channels with two cover plates. It is conceivable that one of those channels may have a weight of $102\frac{1}{2}\%$, and the channel on the opposite side may have a weight of $97\frac{1}{2}\%$. We can also conceive that one of the plates has a weight of $102\frac{1}{2}\%$ and the other a weight of $97\frac{1}{2}\%$. A column so built will have eccentricity due not only to difference in the weight of the material but to the different manufacturing stresses set up by the punchings of the members themselves. The channel that weighs $102\frac{1}{2}\%$ is going to act in a different way from the lighter channel and the same with the plates. Having in mind all the possible variations permitted in our specifications for rolled material, and having in mind the fabrication stresses, the thing I want to know is what is the safe unit load to use.

Mr. Stern: I believe, Mr. Davidson, that Professor Basquin in his original paper called attention to that variation in weight. With regard to the other question, I thought Professor Basquin made an attempt to answer that in calling attention, as he did, to the diagrams that had been drawn and also to the fact that his compromise curve was so close to the other curves that there really was not much difference. As I understood it, he made the statement that he wanted to see whether that same result could be arrived at from a logical premise, and he seemed to arrive at it.

Mr. Davidson: Then the result of all this discussion simply means that the old, well-known straight-line formula is a safe formula to use.

Professor Hayford: I would call Mr. Davidson's attention to a statement of Professor Basquin's under the caption, "Summary of Paper," reading as follows:

"That" (among other conclusions) "while the empirical method may be satisfactory for columns of ordinary size and proportion, a rational method seems essential in the design of very large compression members or those of unusual form."

From talking over this matter with the author, I think I interpret him rightly when I say that of course we can use formulae which have been used in the past, like any of the formulae given under the caption "Column Formulae," or this compromise formula, *for ordinary cases*; but when we undertake to deal with the extraordinary cases outside the range in which those formulae have been thoroughly tested out and in which they are based directly on expe-

rience, then it becomes necessary to use a rational method of extrapolation. So that one of the answers to Mr. Davidson's last remark is this: The result of all this discussion may be summed up, possibly, by saying that within the usual limits of length and form that have been used very frequently, we can keep on as we have been going; but whenever we are dealing with an unusual case, then it is very important to proceed on a rational basis; otherwise the extrapolation will be wild.

P. W. Leisner, M. W. S. E.: It seems to me that the deformations in the steel due to punching might possibly not leave such high stresses as the author has calculated. I think we may assume a certain amount of plasticity in the metal; although the metal has been deformed, the stresses may have disappeared. Punching is a violent process, and the metal may hardly be expected to maintain its elasticity throughout the process, but of course there will also be some elastic deformations. In riveting, the material is again deformed, metal is forced from one place to another by the riveting machine under a process of heat and pressure. The metal is still hot after the pressure has been taken off, and this will permit it to dispose of some of the elastic deformations. Of course, the stresses calculated by the author give us an idea of what the maximum might possibly amount to, and I think that information is very valuable. Also I think it is always valuable to have investigations by learned people. It gives us some idea of what tremendous strains might be expected if certain possibilities are eliminated, as, for example, plasticity. If taken seriously by the designer, as I think they should be, the investigations will always tend to develop a better sense of responsibility, and the designer will understand better just what he is doing.

We must, of course, have a column formula to guide us in designing columns, and whether it should be the straight-line formula or the Rankine formula it seems to me matters very little. If we compare the American Railway Engineering Association formula with the Rankine formula, using a coefficient of 1 divided by 13,500 for the latter, then we find a short column will have a factor of safety of $3\frac{1}{4}$, assuming the ultimate resistance to be 52,000 lb. per sq. in.

If we compare them at a value of $\frac{l}{r} = 100$, then we find that these

two formulae will give the same permissible unit stress and that the unit stress will have a factor of safety of $3\frac{1}{4}$. This factor of safety is taken on the basis of the Euler limit. Now, it seems to me this is something worth observing. The Euler formula has, through thousands of tests, been proven fairly accurate. By "fairly accurate" I mean that it has proven more accurate than any other column formula, when applied to columns of slenderness ratio exceeding 100. It must, of course, be tested for columns for which it is advocated. All the results of these tests have ranged within such a close

belt that we can say it is really the only column formula which is of any value as a mathematical formula. All tests made on columns of less than 100 radii are plotted all over the sheet. One cannot find any column formula that will follow any of them. These two formulae have, I might say, the same factor of safety at both ends.

As to the question of whether we should use the Rankine formula or the straight-line formula, it has been pointed out in the discussion that designers need a simple formula. I do not know to which formula the author of the discussion is bowing. Any formula that has been seriously advocated to date is so simple, so little complicated, that it certainly makes no difference whether one makes a table from that or from a straight-line formula. There is no

designer who, every time he has a column to design, finds his — $\frac{l}{r}$

equal to something and three or four decimal places behind, and then calculates the allowable unit stress. He refers to a table, of course, and takes the nearest even figure. That means 42, 40, 38 and so on, whatever the figure is. Generally, the less knowledge one has of all these tests and analyses made by competent people, the more minute he will be in getting down to the last decimal point, which is very time-consuming labor.

I should like to point out something that I mentioned in a previous discussion before this Society. It has to do with columns with a slenderness ratio of more than 100. We never design, or at least we should not design, if we want to live up to most of the specifications in use, columns for which the slenderness ratio exceeds 100; but in analyzing the strength of old bridges it is necessary to have a column formula which will give some idea of the basis of stress in the compression members. It is utterly impossible to use the straight-line formula in such cases. The Rankine formula for a slenderness ratio of 210 will still allow a unit stress of 4,000 lb. per sq. in., and this represents, on the basis of the Euler limit, a factor of safety of nearly 2. The straight-line formula allows no stress for such a column. I think it is quite logical to expect the formula to allow a stress in such a column, because a column is

not incapable of sustaining stress simply because — $\frac{l}{r}$ is longer than

210. I see in this feature a very good reason for keeping on with the Rankine formula in railway engineering departments. I think it is a good formula.

On lattice bars, if we assume a column section composed of two parts connected with lattice bars, then it seems to me that we are, according to most specifications, putting a premium on using long columns, because, if we take a short column with that section, then we may assume that the transverse shear would amount to a

certain percentage of the load imposed on the column, and if we take a long column of the same section we would assume the same percentage, but a smaller superimposed load. Thus we get less shear on the long column and consequently less stress in the lattice bars, as these will be made the same in both cases; they are determined by the distance between the connection rivets only, according to the present specifications, and the length of the column to which they are applied does not enter into the determination of the lattice bars. I do not know whether it is necessary to go into an investigation of this relation, but it seems as if, as I said, a premium is placed upon using the long column, as far as lattice bars go.

To become a good detailer is an ambition worthy any engineer. I do not think any engineer, whatever his standing, should consider this a modest ambition. To compute stresses is a simple mathematical problem, requiring very little thinking. Bridges in the details often require most painstaking effort and in some cases a knowledge of mechanics to an extent that far exceeds the knowledge required for computing main stresses. I should advocate great attention to details, on the part of designers. It is something that they cannot call upon the scientific men to do, because this subject cannot be standardized. Designers should make that part their specialty. They should go into the matter and see all of the different sides of it. It would open the eyes of many of them to difficulties that had not been thought of before, and then they should also, in their spare time, pay close attention to all the tests that are made, particularly the analysis of them as presented by competent men.

Mr. Davidson: I would like to ask the author if he believes that engineers would be safe in assuming a higher unit stress for a rolled section used as a column than for a built-up column. I have reference particularly to permissive unit stresses for Bethlehem H section columns.

My own practice has been to use 18,000 lb. fiber stress reduced by the straight-line formula for Bethlehem columns in building work. Some five years ago the first building in the West in which Bethlehem sections were used was one that I designed. I designed it for Bethlehem shapes throughout and used 18,000 lb. fiber stress reduced by the well-known straight-line formula. A competitor of the Bethlehem Steel Company went over my head, to my superior officers (I was employed at that time by the Western Electric Company); he even went to the president of the company. The result was I had a meeting in Chicago with Mr. C. C. Schneider, consulting engineer of the American Bridge Company. The matter was discussed thoroughly and Mr. Schneider went on record to the effect that I was correct in my assumption; that I had the right to assume higher stress in the rolled section shape than in any possible built-up column, due to the fact that in any built-up column there are fabrication stresses that do not occur in a rolled section.

Mr. Basquin: In the discussion Mr. Carpenter says: "Stocki-

ness of material is a matter the author has not more than touched upon and which is doubtless one of great importance. Tests of record seem to indicate no superiority in strength of solid sections, such as rolled H-columns and lap-welded tubing, over built riveted sections (except perhaps for very short length ratios), nor any necessity for deducting filled rivet holes in considering the section of the latter."

I am not particularly well informed upon that subject, but Mr. Howard made tests on some small sized Bethlehem sections about three or four years ago, also on tubing, and they showed the elastic limit to be about the same as riveted sections and strength also not very different from them.

Mr. Davidson: I will state, for the author's information, that there are one or two other engineers in Chicago, who are using these higher stresses, and we have not yet had any buildings fall down.

Mr. Basquin: My recollection is that those sections begin to show excessive strain, indicating a proportional limit stress not far from 20,000 lb. per sq. in.

Mr. Vent: For the Fisher Building, I believe the proportions were 18,000 lb., and that is the Gray column without any center web. That building was twisted out of shape when they put it up and had to be straightened, but it is still standing.

Mr. Basquin: Mr. Godfrey seems to class the paper quite largely with other papers that are not of any special benefit to the engineering profession. That is to say, his view is that there is too much discussion of columns, that we ought to adopt the straight-line formula and let it go at that. He says:

"The engineering profession is not nearly so ignorant of the strength of full-sized compression members as some of its members would have us believe. It is true that the exact ultimate strength of columns (not slender) cannot be accurately told, but it is just as true that a perfectly safe column can be designed and built for any given load without wasting material, and this is the kernel of the matter so far as designers are concerned."

I wonder if it is entirely logical to say that we do not know the load at which a column will fail and yet we can determine a design so that the column will be perfectly safe and yet not waste material.

Professor H. F. Moore makes what seems to be a valuable suggestion on the method of measuring the efficiency of the lattice. I had the privilege of measuring this efficiency for a good sized column made by the Chicago Steel Products Company. The webs were two 15-in. I-beams, 42 lb. The cover plates were two 20 x $\frac{1}{2}$ in. and two 20 x $\frac{3}{8}$ in. plates. The column was 45 ft. 5 in. between bearings. In measuring the deflection we used a fiber stress of 1620 lb. per sq. in. and got an efficiency of 99%. In putting the strain gauge on and measuring the strain we used a fiber stress of 3250 and got an efficiency of 96%, and also a fiber stress of 4450

lb. with an efficiency of 103%. These values are all so near 100% that the variation from that is probably due to errors of observation, so we can conclude that in the case that we have tested, the efficiency was practically unity.

Mr. Carpenter seems to think that the object of the paper is to find fault with ordinary columns as designed, to suggest in general that they are not safe. The object that I had in mind, as I see it myself, is quite different from that. I am not saying that the columns in this building are not strong enough to hold up the building. I would not suggest that about any particular case. What I am suggesting is this: In columns we have certain phenomena as the load comes on. In beams we have certain phenomena. Our discussion of beams corresponds quite largely to the phenomena that occur in beams when they are being loaded, but our discussion of columns is entirely distinct from the phenomena that occur in the columns themselves. We ought to make the discussion of columns depend upon the phenomena in columns and not have it entirely apart. Whatever happens in the column ought to be taken into consideration in the design. That is not saying that this should be done in every individual case. I am not advocating that, for every individual column, one should figure out the eccentricity, but this ought to be in the mind of some one when the dangerous stress for which a column is designed is settled upon.

SOME EXPERIMENTS ON HIGHWAY BRIDGES UNDER MOVING LOADS

F. O. DUFOUR*

Presented before the Bridge and Structural Section March 10, 1913.

INTRODUCTION.

For several years experiments on highway bridges under moving loads have been carried on by the Civil Engineering Department of the University of Illinois, assisted to some extent by the State Highway Commission, to obtain, if possible, information which would lead to more intelligent design, since it was thought that the

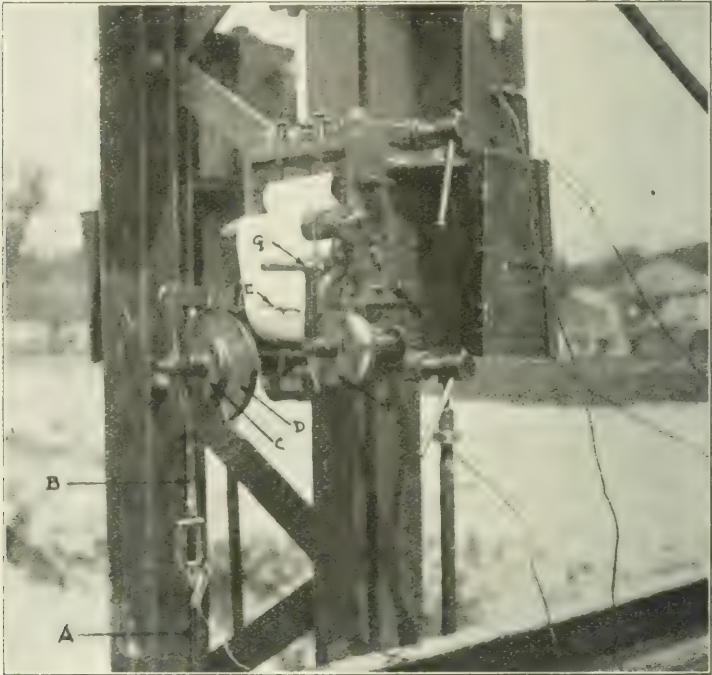


Fig. 1. The Deflectometer.

impact requirements of specifications were not justifiable, and that the limitations of fabrication and erection introduced conditions which modified considerably the theoretic stresses.

These experiments have been under the direction of the writer. They are not complete, but when they are the results will be published in full in an Engineering Experiment Station Bulletin in case the information obtained is of sufficient value to justify it. The

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matter contained in this paper is, therefore, presented as information, and is to be considered as a progress report.

APPARATUS.

Two classes of instruments were used,—one for measuring the deflection of the structure as a whole, and one for measuring the elongations and compressions of individual members. Of the first class there was one and of the second class six instruments used in these experiments.

(1) *The Deflectometer.* The instrument used to determine the deflection of the structure was a Frankel deflectometer, Figure 1

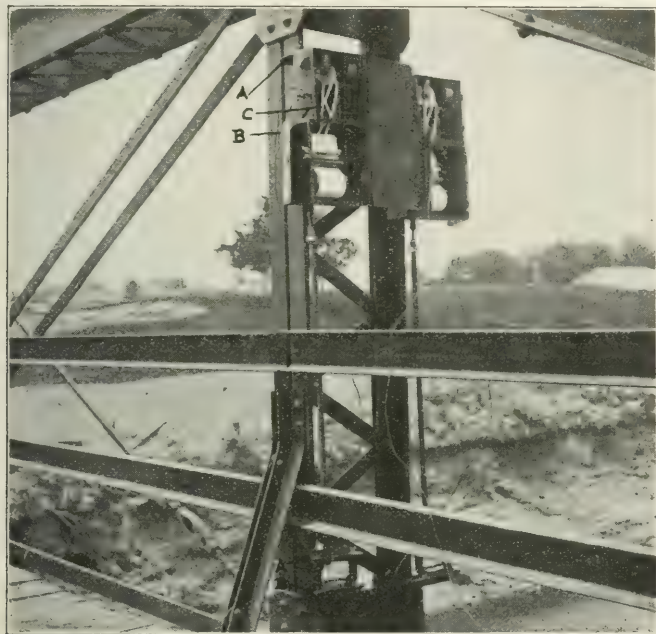


Fig. 2. The Extensometer.

shows it attached to a bridge. Connection is made by means of a wire *A* to a heavy weight placed on the ground or bed of the stream. The wire is connected by a steel ribbon *B* to the circumference of the disk *C*, which is attached to a disk *D* twice the diameter of disk *C*. A second steel ribbon carrying a carriage *E* is connected to the circumference of disk *D* and also disk *F*. Disk *F* is hollow and has an interior spring which keeps the steel ribbon and the wire taut. A roll of glazed paper on one spindle is made to pass under the carriage *E* at a rate of about 0.4 in. per second and roll up on another spindle by means of an electrically-controlled clockwork. The carriage *E* carries a brass needle and when the structure de-

flects, this needle moves horizontally a distance twice the deflection and makes a continuous record on the paper as it passes under it, thus forming an automatic and autographic record of the test. (For a further description of this instrument, see *Trans. Am. Soc. C. E.*, Vol. 41, page 411.)

(2) *The Extensometer.* This was of the Turneure type as designed by Dean F. E. Turneure, of the College of Engineering, University of Wisconsin. Figure 2 shows two instruments attached to a vertical of a pony truss. The deformations are multiplied about fifty times, the total gage length being about 48 in. The recording apparatus is at C. The instrument is connected by

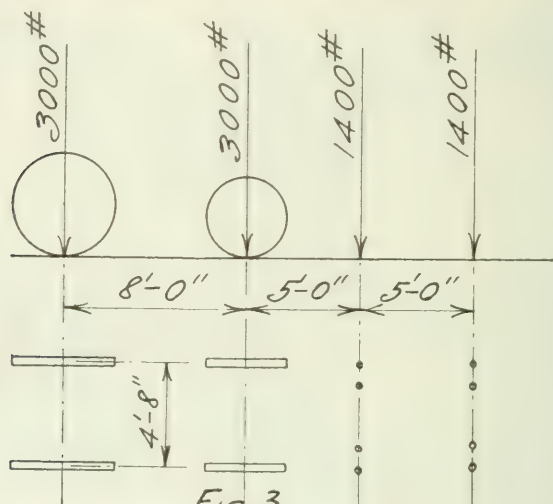


Fig. 3.
8,800 lb. Wagon and Two Horse Team.

clamps at A and B. An electrically-controlled clockwork similar to that of the deflectometer causes the paper to pass under the metallic recording needle at the end of the lever C, causing an automatic and autographic record to be made. The calibrations of the instruments gave slightly different stress scales. The average stress scale for the diagrams was 12,000 lb. per linear inch. (For a complete description of this instrument see *Trans. Am. Ry. Eng'g. Assoc.*, Vol. 12, Part 3, 1911, p. 18; *Engineering News*, June 20, 1907, p. 681; *Railroad Gazette*, Vol. 52, p. 444.)

GENERAL DESCRIPTION OF THE EXPERIMENTS.

The experiments consisted in obtaining deflection and extensometer diagrams under several classes of moving loads, from a number of bridges in Champaign and La Salle counties, Illinois. Usually from four to six records were taken from each member

of each bridge. The number of bridges tested, their spans, and floor characteristics are:

- 1— 55 ft. reinforced-concrete floored pony truss.
- 1— 70 ft. plank floored through truss.
- 1— 78 ft. reinforced-concrete floored through truss.
- 1—105 ft. plank floored through truss.
- 1—110 ft. reinforced-concrete floored through truss.
- 1—144 ft. reinforced-concrete floored through truss.

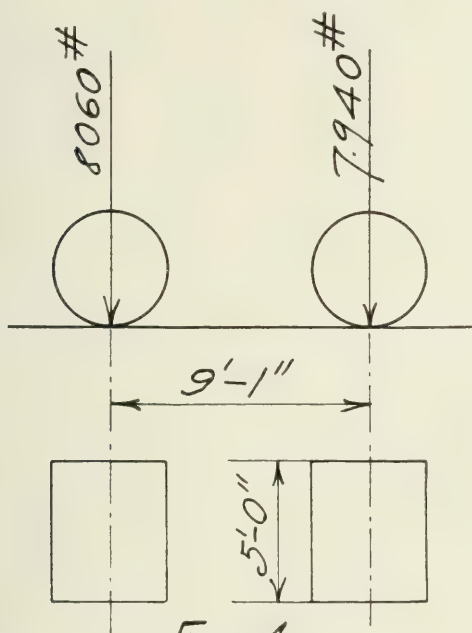


Fig. 4.
8-Ton Street Roller.

- 1—160 ft. plank floored through truss.

The clear width of roadway was from 14 to 16 ft.

Five different loadings were used, but all bridges were not tested with all classes of loads. The loads, together with the average uniform load per linear foot of wheel base, are:

- 1. 1700 lb. single horse and buggy, 113 lb.
- 2. 4300 lb. automobile, 430 lb.
- 3. 8800 lb. double team and load of lumber, 490 lb.
- 4. 12-ton farm engine with 13-ton stone wagon, 1500 lb.
- 5. 8-ton street roller, 1700 lb.

Figures 3, 4, 5, 6, and 7 give the weights and wheel bases of the loadings.

A 100 ft. base line was laid off over the span and passage of the load was determined by stop watches. From these data the speed of the load was calculated. In later experiments a graph, Fig. 8, was constructed and the speed taken directly from it.

RESULTS OF EXPERIMENTS.

The discussion of these experiments may best be divided into the following parts:

1. Impact.
2. Variation of Stress.
3. Distribution of Floor Loads on Joists.

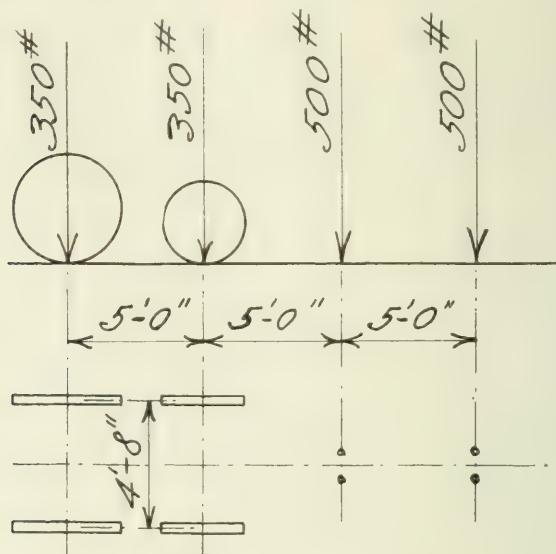


Fig-5.
1,700-lb. Horse and Buggy.

4. Comparison Between Actual and Computed Stresses.
5. Conclusions.

Impact. The percentage of impact was found to depend upon the speed, the class of floor, the weight of the load, and the construction and position of the member.

Figure 9 shows the percentage of impact produced by the 1700 lb. horse and buggy, and Fig. 10 shows the percentages for the 4300 lb. automobile. These results are computed from the deflectometer records. The maximum impact percentage values as determined from the extensometers are plotted in Fig. 11.

An inspection of Figs. 9, 10, and 11 shows that there is a

critical speed; that the lighter the load the greater the percentage of impact; that for equal spans, concrete floor bridges have considerably less impact; that extensometers and deflectometers do not indicate the same maximum percentages of impact under the same loading and speed; and that there is apparently no relation between impact percentage and span length. It is interesting to note that in the case of a horse and buggy, Fig. 9, the impact percentage for

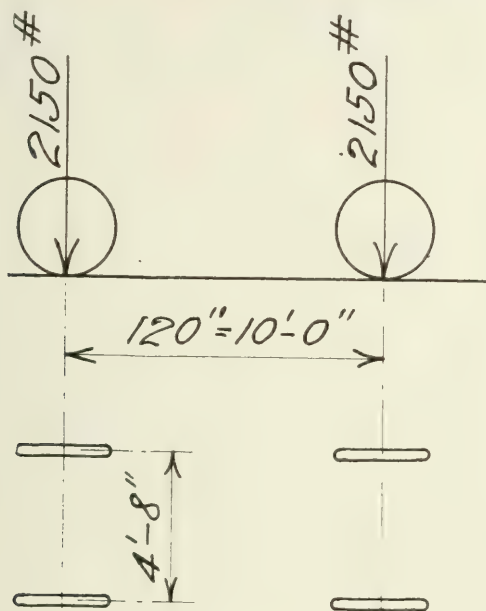


Fig-6.
4300-lb. Automobile

the trot is the highest, while for the walk and gallop it is much lower.

The variation in the impact percentages and the computed stresses in the case of one bridge, the loads varying, is shown in Fig. 12. This clearly shows that the percentage of impact increases as the loading decreases.

Figure 13 shows that the impact percentage is less in built-up members than in simple sections, and that the percentage of impact varies according to the location of the member. The 55 ft. span has built-up hip-verticals. The 78 ft. concrete floored span has a much less amount of impact than the smaller plank floored span.

Note that the deflectometer reading is not an indication of the maximum impact percentage.

In order to compare the actual impact stresses with those computed by the various formulæ which have been suggested from time to time, Fig. 14 was plotted using the 78 ft. reinforced-concrete floored span and the 8-ton roller. The results indicate that the actual impact stresses are very small and that the impact formulæ are practically valueless.

That the impact percentage varies with the speed and with the class of floor is indicated by Figs. 15, 16 and 17, all compiled from extensometer diagrams. These are typical diagrams. They show that for plank floors the impact percentage increases consid-

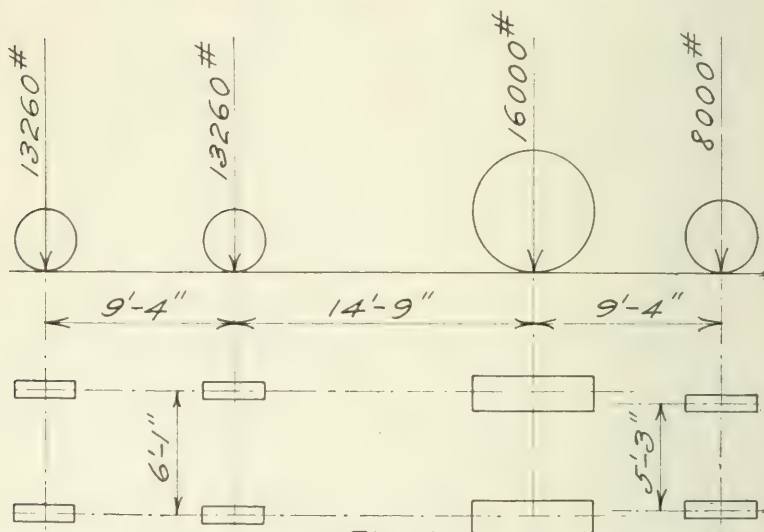


Fig. 7.
12-Ton Farm Engine with 13-Ton Stone Wagon.

erably as the speed increases, but little or no impact is shown by the diagrams from the reinforced-concrete floored span. A peculiar fact is to be noted,—that the stresses in the reinforced-concrete floored span members are very small, probably due to the fact that the floor distributes the load over the entire span.

The percentage of impact as indicated by the deflectometer records from plank floored bridges may be expressed by the equation

$$I = 210 - 2l + 0.009 l^2$$

where C is the span in feet. This is plotted in Fig. 18, and is here given as a matter of interest rather than of practical value.

Variation of Stress. Results indicate that the stress is unevenly distributed over the section of compression members, and

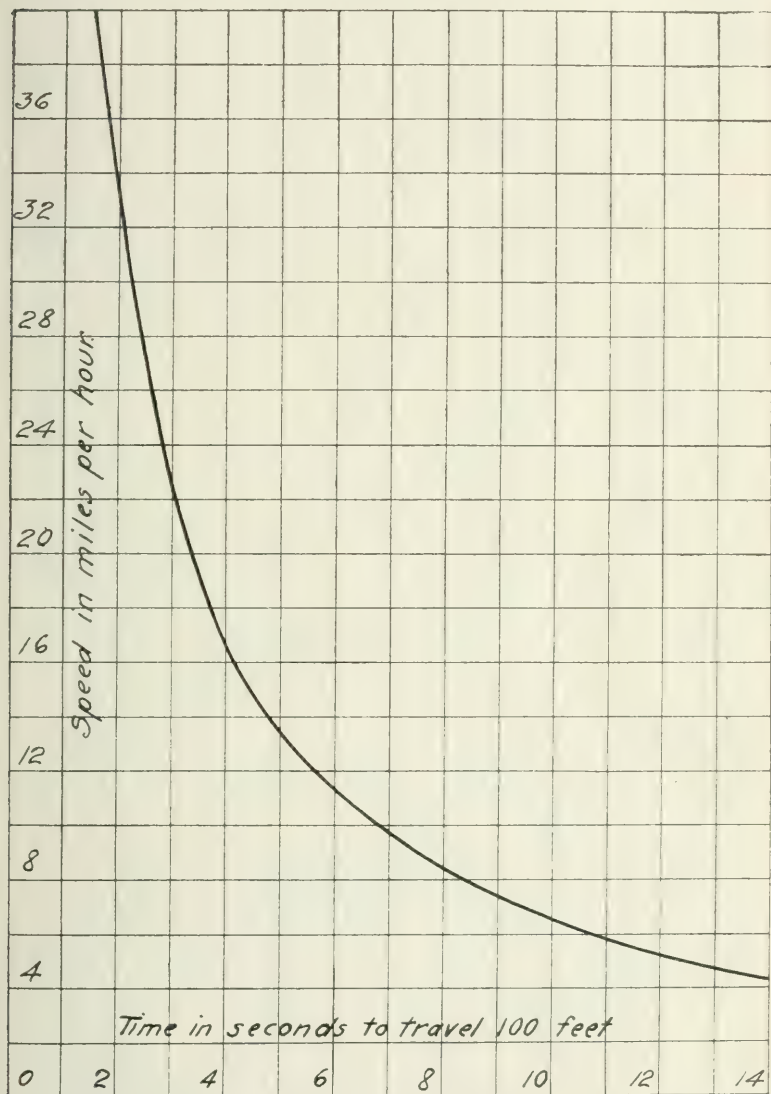


Fig. 8. Speed Graphic.

that tension members composed of bars do not have the bars equally stressed. Figures 19 and 20 show this. Figure 20 also shows

that the east truss bars did not pull equally with those in the west truss.

Distribution of Floor Loads on Joists. In the design of joists, it is important to know the distribution of the concentrated load on

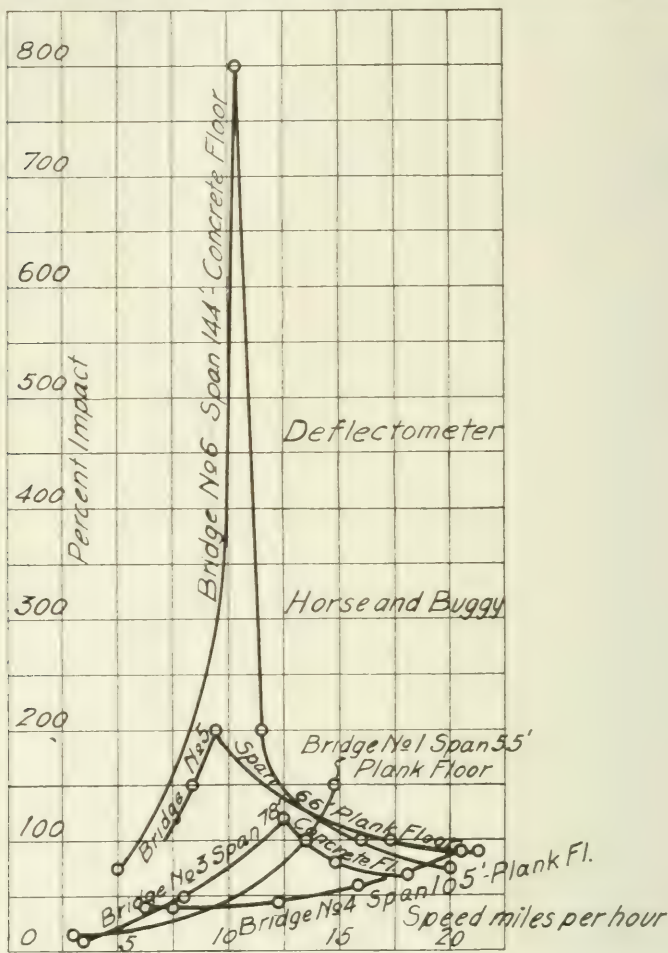


Fig. 9.-Impact Percentages
1,700-lb. Horse and Buggy

the floor. Results of experiments on concrete floors are plotted in Fig. 21. They show that each joist carries a portion of the load. The results here shown indicate that 21% of the total load, or 42% of a wheel load, is carried by one joist. This is slightly more than the 33 1/3% assumption in common use. These results are the

mean of a considerable number of tests. The one test made on a plank floor showed that the maximum load carried by a joist was 44% of the total load, or 88% of a wheel load.

Comparison Between Actual and Computed Stresses. A comparison of computed and actual stresses shows that the computed stresses are less than the actual in nearly all cases and that the difference is much greater in reinforced-concrete floored spans than in plank floored spans. Figure 22 shows the values for two spans.

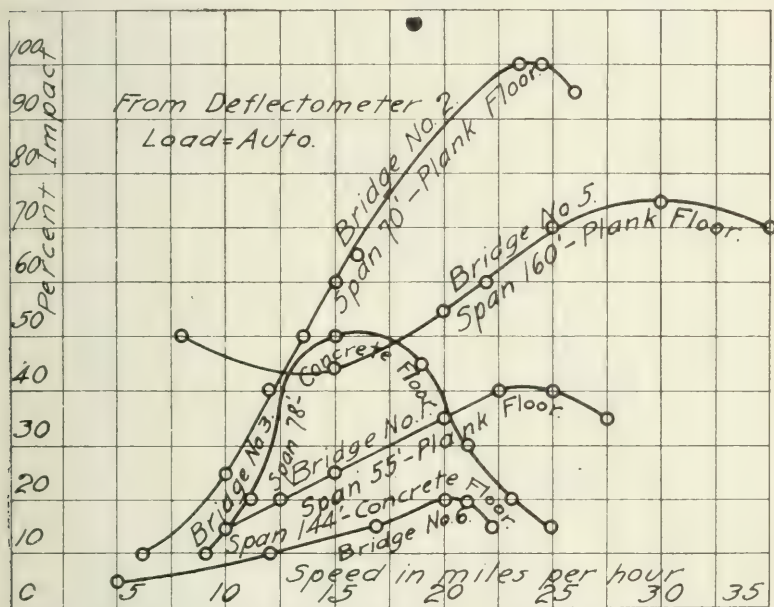


Fig. 10. Impact Percentages - 4300-lb. Automobile.

The over-run of the actual in the case of the main diagonal U_1 , L_2 is due to unequal tension in the bars composing this member. The greater tension bar is here plotted. A careful scrutiny of the results of tests shows that in the case of the reinforced-concrete floored bridges few actual stresses exceeded 50% of the computed static stress. This is probably due to the fact that the load is distributed over the entire span and acts somewhat as a uniform load.

Conclusions. Conclusions to be derived from the results of the experiments are:

1. That built-up members are superior to single shapes.
2. That light loads produce the greatest percentage of impact, but that the light load static stress, plus the light load impact stress, does not exceed the static stress for which bridges are usually designed.

3. That reinforced-concrete floored structures are much superior to the plank floored structures.

4. That on account of the fact that the stresses produced by heavy loads in reinforced-concrete floored structures are very small, the impact percentages were difficult to determine and that the values given are probably far in excess of the actual, which appeared in the majority of cases to be zero.

5. That actual stresses in reinforced-concrete floored bridges may be assumed as one-half the computed static heads.

6. That considering conclusions 1 to 5, we may safely neglect

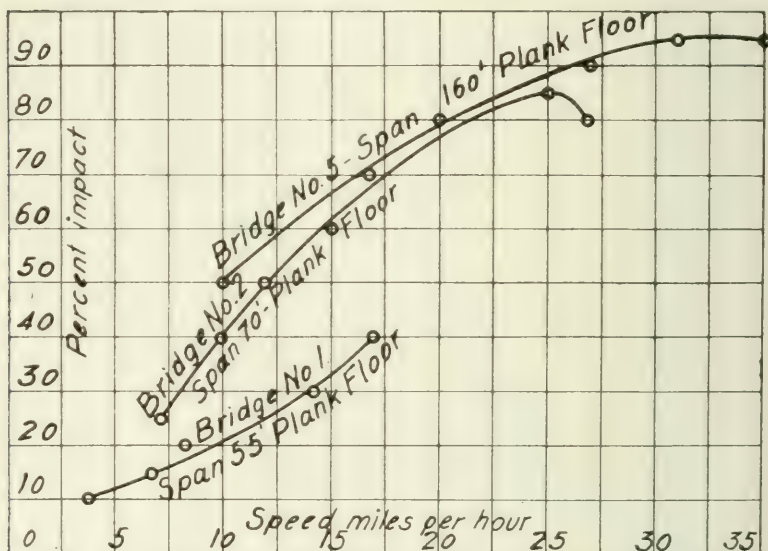


Fig. 11.—Impact Percentages determined from Extensometer Diagrams from Compression Members. Load—4,300-lb. Automobile.

impact in reinforced-concrete floored bridges, and that we may assume each joist to take 20% of the wheel load or 10% of the axle load.

DISCUSSION.

Professor Dufour: I want to express my appreciation of having been asked to present to you a paper, and while some of the things given in this paper are new and unexpected, it is quite possible that many of the engineers present will have anticipated the results, to a considerable extent.

We have taken several thousand diagrams, as you can well imagine, and have worked them over very carefully, with these results. I presented most of these lantern slide views several years ago in an informal manner before the Association of State High-

way Engineers, and they immediately took impact out of their specifications. I am informed by several of the state engineers of our near-by states, including our own, that they have saved from \$30,000 to \$40,000 on their bridges in one year, by not considering impact in cases where the material for the floor has been reinforced concrete.

J. H. Prior, M. W. S. E. (chairman): Professor Dufour's men-

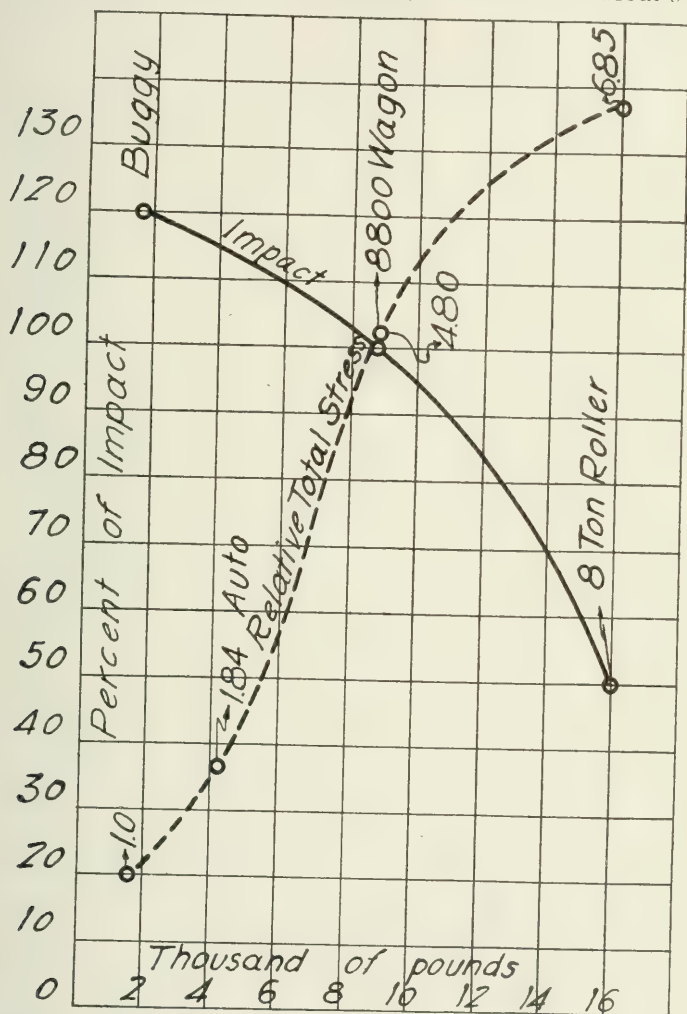


Fig-12-Variation of Impact Percentages with Varying Load.

tion of critical speeds brings to my mind an incident on a western road.

The railroad had completed a new long-span bridge designed for heavy loading. Although it was known that the bridge was a modern, first-class bridge, it was thought, on account of the great length and height of the spans, that a slight restriction in speed should be made in crossing the bridge, and it was therefore suggested that the speed be restricted to the rather high limit of 45

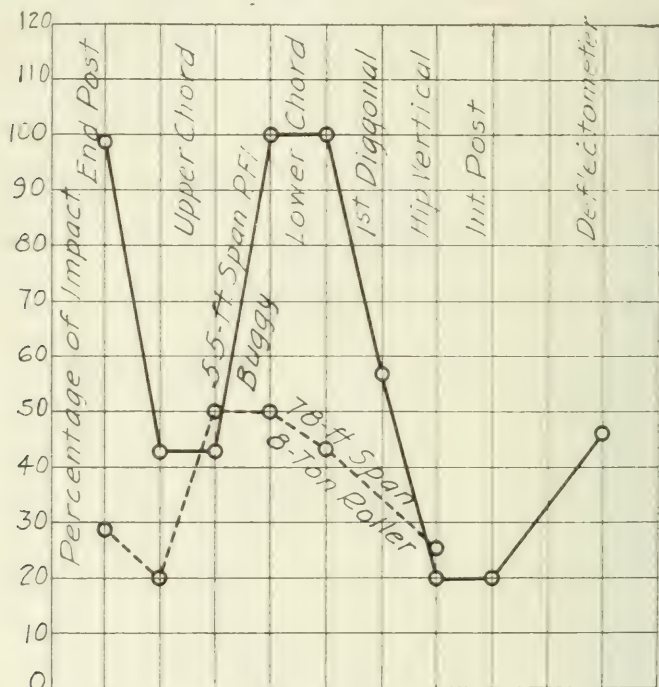


*Fig. 13.—Variation of Impact Percentages
Different Members—Different Loadings.*

miles per hour. Now, 45 miles per hour happened to be the critical speed for that bridge.

Professor Dufour: Referring to Fig. 9, where an 800% impact was obtained by a 1700 lb. horse and buggy, on a 144 ft. reinforced-concrete floor span, it happened to be the critical speed of the bridge. The bridge began to bob up and down and some of the men wanted to run off. I told them there was no use running; it would fall before they got to the end; they might as well stay and see it out. We do not know what the total deflection was, because the instrument rocked back and forth as far as it would

go and the wires kinked up. The deflection measured was about $\frac{3}{4}$ in.

Mr. Prior: Did you measure that deflection?

Professor Dufour: Yes, from the deflectometer. We had a similar experience to that of Mr. Prior. We came to a bridge which had a sign posted, saying, "Horses shall not go across this bridge faster than a trot." We told the commissioners to tear that sign down and replace it with one saying that horses shall not go across the bridge at less than a run.

Mr. Prior: By the limits Professor Dufour has selected, faster

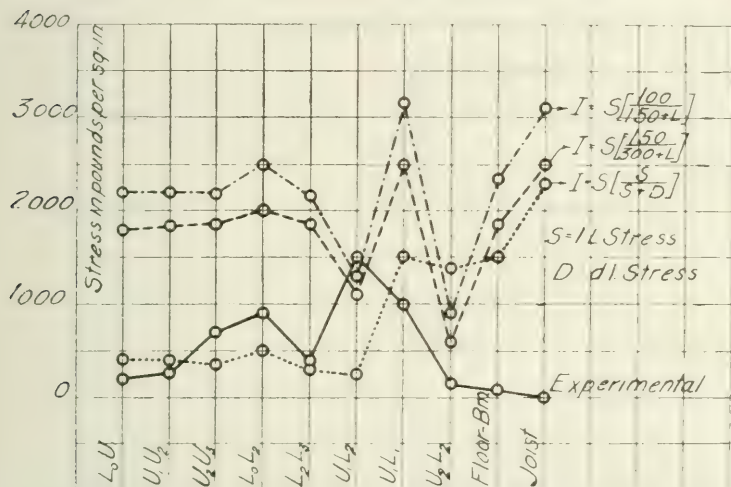


Fig. 14 Comparison of Actual with Computed Impact Stresses
18'0" Reinforced Concrete Floor—8-Ton Roller

horses come out of Urbana than any I ever sat behind in the state of Illinois. Forty-two miles per hour was the upper limit, I believe, as shown.

The earliest information I received on impact, was the statement made at one time that a dog trotting across Brooklyn bridge gave greater stress than a heavily loaded team, which, from the author's investigations, may not be so far from the truth.

President Reichmann: I think engineers ought to allow a liberal amount for impact, possibly not so much on account of the impact itself as on account of some things that were mentioned in the paper, namely, the uneven distribution of the stress over a great many of the members. I am quite well satisfied that some of the eye bars the author mentioned were not bored true to length, in which case various eccentric connections and stresses are produced, which must be provided for through some rule. I think it is a well established fact that the shorter a structure, the more difficult it

is to get a vertical connection. There is, therefore, a greater amount of eccentricity in our connections, and, consequently, heavier secondary stresses, and these have to be provided for either by reducing our unit stresses or else applying some impact formula. I think, for that reason, our impact formulæ, while they do not provide

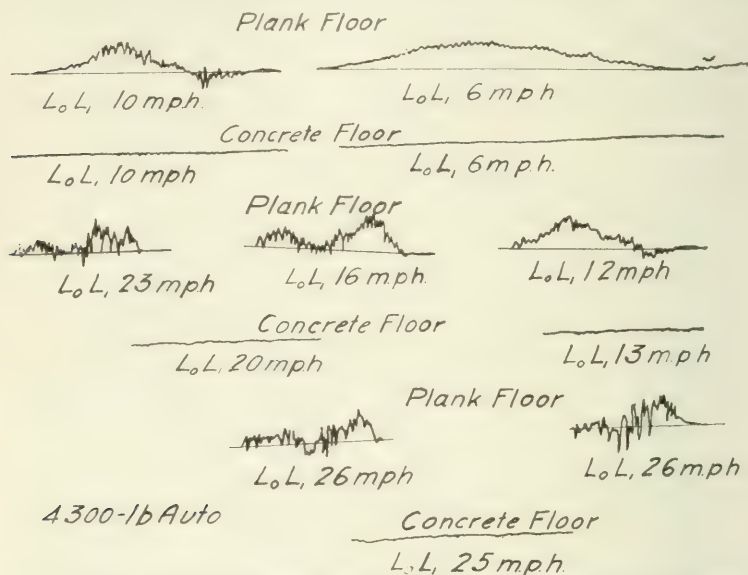


Fig. 15 - Comparative Diagrams Plank and Reinforced Concrete Floored Bridges. Span 70'-0" P.F. Span 78'-0" C.F.

for pure impact stresses, they do provide for a number of conditions which must be provided for in some way.

I saw the report of Professor Turneure on bridge investiga-

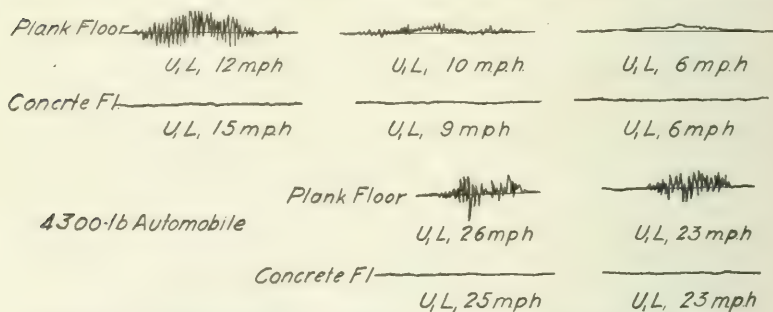


Fig. 16 - Comparative Diagrams Plank and Reinforced Concrete Floored Bridges. Span 70'-0" P.F. Span 78'-0" C.F.

tions which he made on some of the western railroads. Some of the bridges investigated were designed by some of the best engineers in this section of the country, and they showed very heavy secondary stresses due to the floor beam connections and the connections for the stringers to the floor beams. We also have stresses

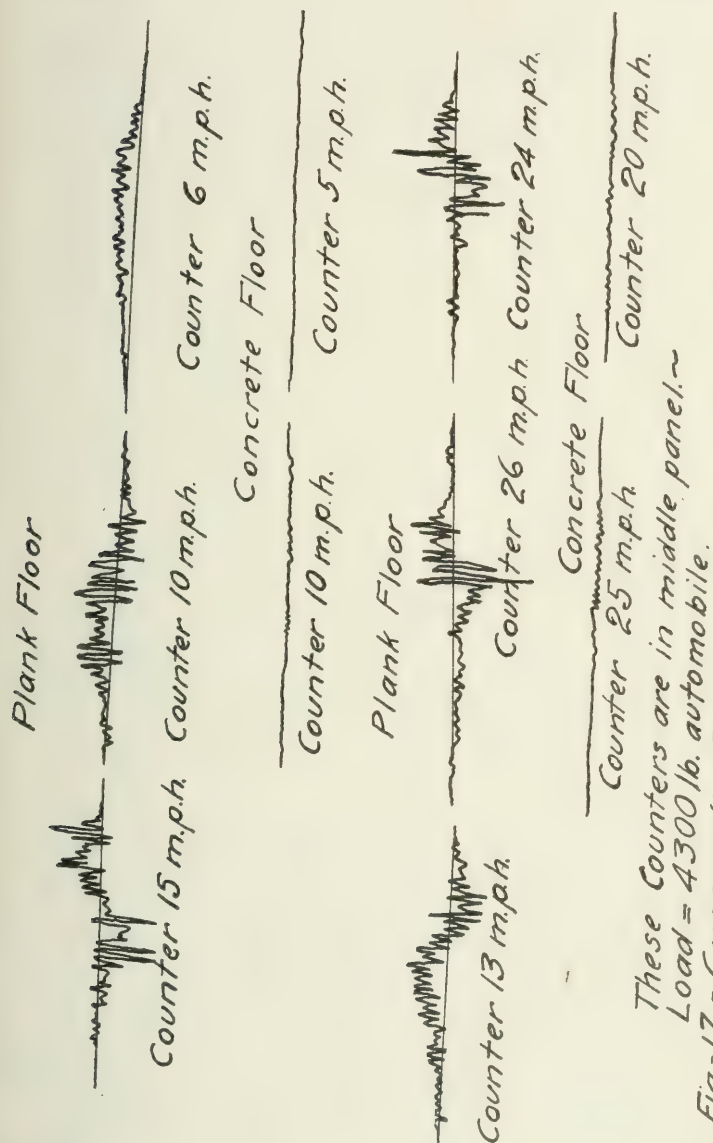


Fig. 17. - Comparative Diagrams Plank and Reinforced Concrete Floored Bridges. Span 70'-0"-P.F. - Span 78'-0"-C.F.

in the chords, eccentric stresses, particularly, that are brought about on account of the difficulty to properly centralize our loads, and for that reason I do not think that we ought to reduce our impact stresses.

In the case of a reinforced concrete bridge there are a great many secondary stresses, or we might say, stresses that are induced there that are very difficult to follow through the structure. I am satisfied that if the bridge floor is thoroughly reinforced the floor really becomes a part of the bottom chord throughout, and for that reason it naturally reduces the stress on the whole structure. Of course, it is a very difficult matter to tell just how this would act, and if we get to longer span bridges we naturally want to cut this concrete slab, to allow for expansion and contraction. As I say, there are many elements of uncertainty which have to be considered.

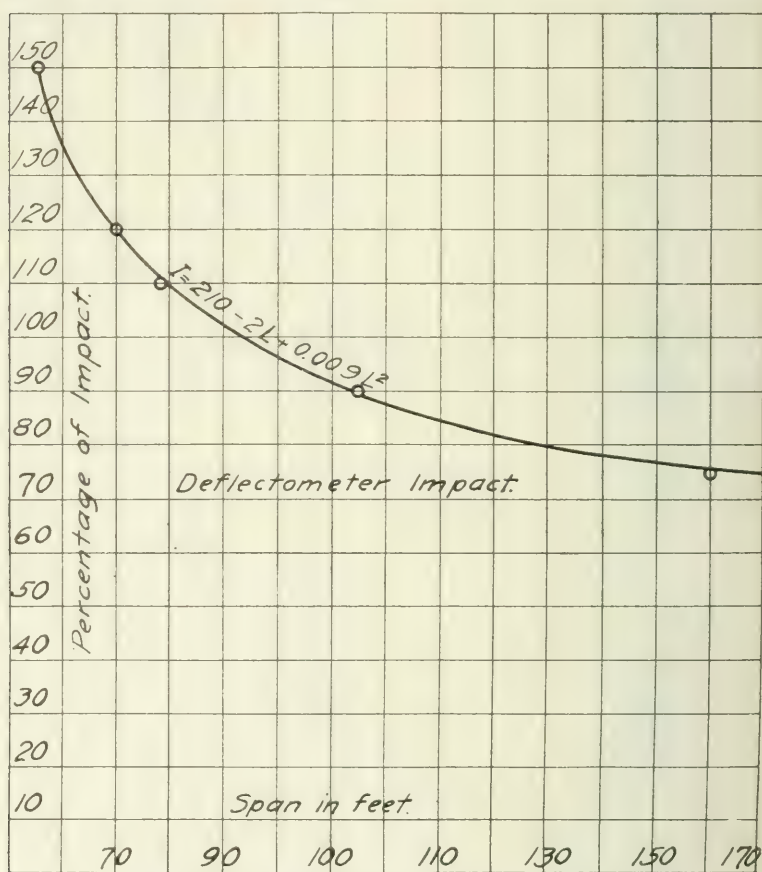


Fig-18- Impact Percentage Graphic.

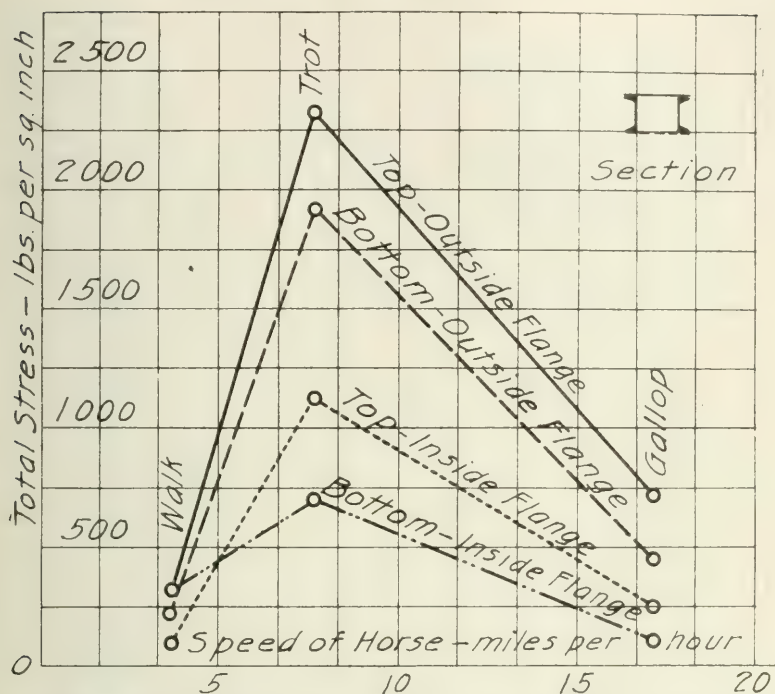


Fig. 19—Variation of Stress. End Post Section.

(Of course, even if we consider the impact in the bridge that has a reinforced concrete floor on it, the percentage of live load is naturally so small that it cannot have the same effect that it would on another bridge. Take the case of a horse trotting across a bridge. The load is applied so suddenly and released so suddenly, that it naturally brings about a very great impact when the structure is light.

Professor Dufour: I fully agree with Mr. Reichmann. I should like to see all highway bridges with plank floors designed with 150% impact; but for the reinforced concrete floor, I do not think we should include any great amount of impact, for the reasons which he states. If we should cut the reinforced concrete floor or provide a joint, then probably the story would be different. The conclusions relative to the omission of impact refer only to reinforced concrete bridges, because we hope that everybody will follow the better specifications and not put in any more plank floor bridges.

President Reichmann: There is another little point I might mention in this connection; for instance, how thick is this floor, 6 in.?

Professor Dufour: The thickness of the concrete floor is 6 in.

President Reichmann: You have a 6 in. floor. That will probably run about 40 lb. to the sq. ft.

Professor Dufour: It will run about 125 lb. per sq. ft. with the earth cushion on and that cushion wet.

President Reichmann: I suppose there is no load passing over the average highway bridge exceeding 50 lb. per sq. ft., considering the bridge as a whole.

Professor Dufour: The engines that we had there gave loads of 100 lb. per sq. ft. for a short distance.

President Reichmann: I believe if we consider that we have

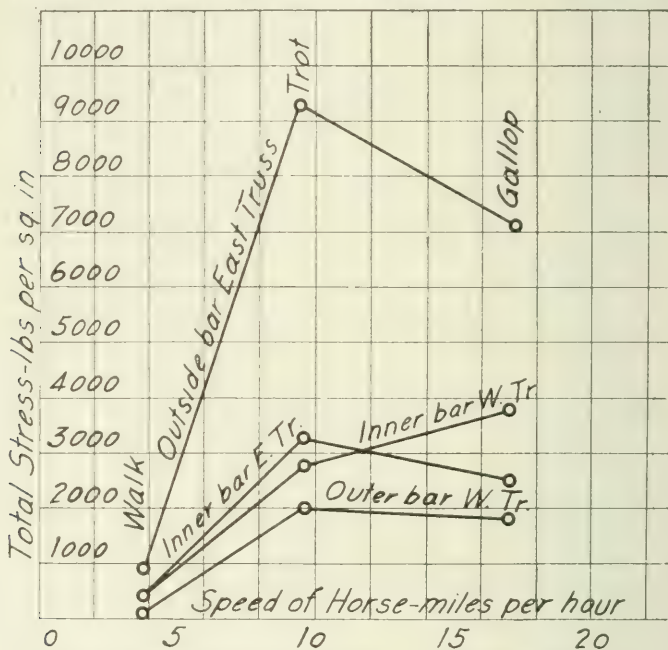


Fig. 20.—Variation of Impact Percentages, Hip Vertical.—Load—1,700-lb Horse and Buggy Span—70'-0" Plank Floor.

100 or 125 lb. per sq. ft. with the dead load, the addition to it is going to be a very small percentage of the dead load, and if we have a reasonable amount of safety to the dead load, the live load would not be of much consequence. Of course, if we take a bar only 1 sq. in. and stress it up to 100,000 lb., we know what we are going to get.

E. McCullough, M. W. S. E.: There are two or three reinforced concrete bridge impact specifications in which the ordinary impact rules given for light highway bridges are called for, and if anybody

can explain why those are used for reinforced bridges I would like to hear the reason.

Mr. Prior: Some impact experiments were made on a reinforced concrete trestle bridge built for the C. M. & St. P. Ry. Co., and I reported the results in the *Railway Age Gazette* of March 23, 1911. These experiments show impact of from 16% to 41%, and this may serve as an answer to Mr. McCullough's question.

W. S. Lacher, ASSOC. W. S. E.: One question arises in my mind,

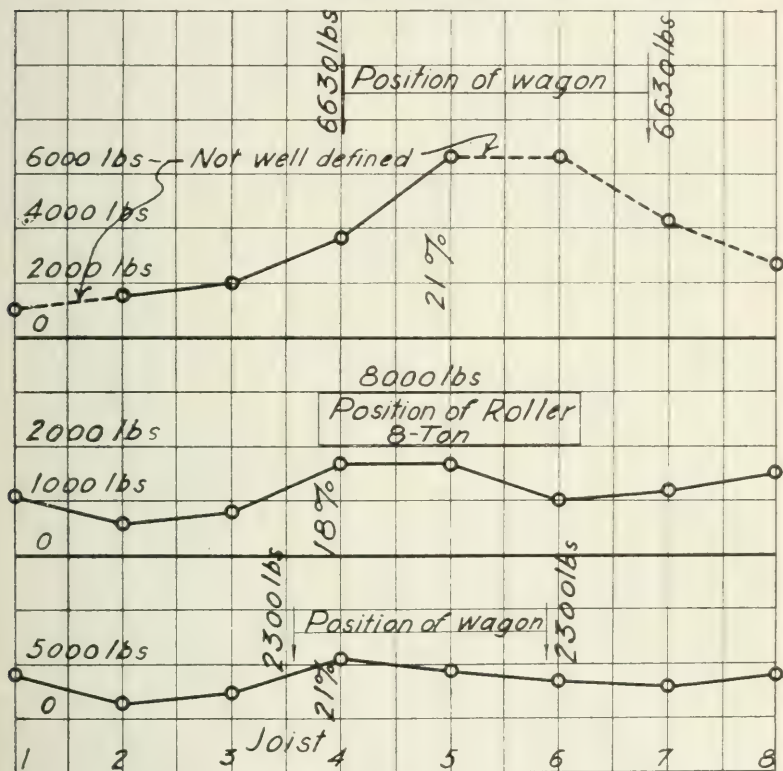


Fig. 21.—Distribution of Floor Loads over Joists.

and that is whether the use of some of the recommendations made by the speaker tonight would not run some of the people selling highway bridges into considerable difficulty. Using their ordinary methods of calculation, with highway bridges, and applying concrete floors, as they are now forced to do in most cases, they often have considerable difficulty in getting the floor on without causing a failure of the bridge.

I am afraid that any statement as to an element of strength obtained by the use of concrete floors will be taken by unscrupu-

lous builders as an argument for still further "skinning" of bridges designed and built without adequate supervision.

Professor Dufour: If anybody designs a reinforced concrete floored highway bridge and then adds 80 lb. per live foot to the trusses, he will get a very heavy bridge. In fact, some of the commissioners objected to bridges I designed on account of the fact that

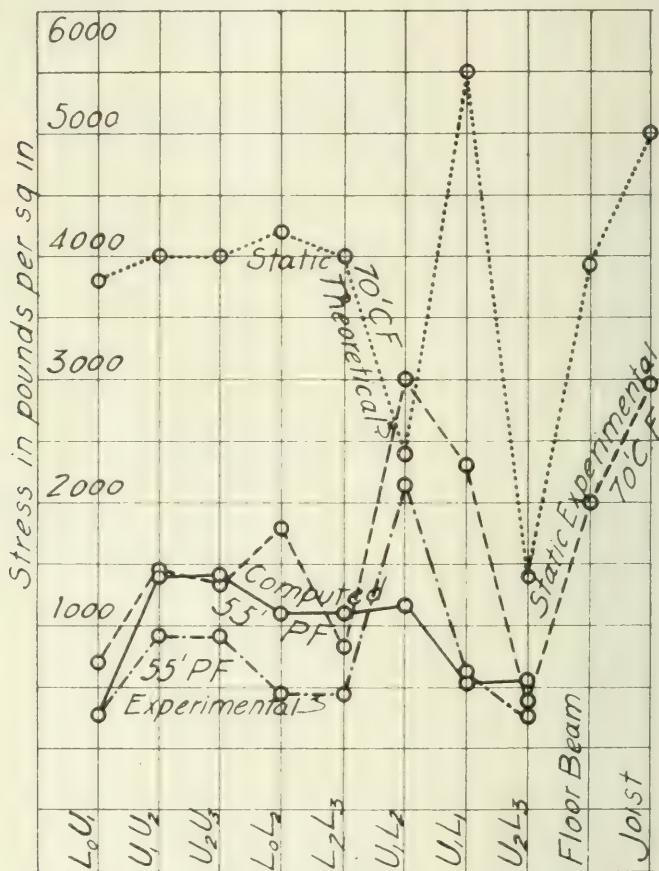


Fig. 22: Comparison of Actual with Computed Stresses.

they could, as one expressed it, run a young locomotive over them. An ordinary highway bridge with a reinforced floor will give a dead panel load of 20,000 lb. That is a good dead panel load for a highway bridge. One cannot design a highway bridge with any less than 10 in. joists, that is, a reinforced concrete floor with any less

than 9 or 10 in. joists and 15 or 18 in. floor beam. The 160 ft. span which was tested had 15 in. channels for the chords, and I consider that a very good highway bridge.

We tested another bridge near Lacon, I think it had a 25 or 30 ft. roadway, two sidewalks, brick pavement on the reinforced concrete base, as I remember it,—I may be mistaken about the base,—and we found that the stresses were exceedingly small, much less than those we would obtain if we computed them. The people thought that the bridge vibrated considerably, but the vibration, as we found out afterwards, was $\frac{1}{8}$ in. They ran loads of pig-iron, the fire apparatus, and a trolley car across the bridge all at the same time; they made a great noise but did not make very much of a stress.

The State Highway Commission has come to the conclusion that we can neglect the impact in reinforced-concrete floored bridges, when we use a good reinforced concrete floor with an earth cushion and then design, in addition to that, for a live load of 80 lb. per sq. ft. of floor surface. This takes care of these various secondary stresses and may be called a sort of insurance factor of ignorance.

We never get such loads on bridges as those for which they are designed. That is the only thing that saves them. If we could get 80 lb. floor load on these bridges I might not be so ready to design them for that, but we never do and when we design them for that amount, it covers the impact stress.

Our tests on reinforced concrete floors showed that the eye-bars pull more evenly; in fact, almost exactly so; while on the plank-floored bridges the tests showed one bar taking most of the stress and the other taking little or none in many cases. Indeed, we found one case where we could wiggle the bar across the pin any way we wanted to, and the other bar was taking all the stresses, but we never found that to be the case with the reinforced concrete floor.

I never do much figuring with dead load for a reinforced concrete floor. I take 20,000 or 25,000 lb., as I think best, and have never had any bridges fall down. I have seen bridges stiffened by putting on concrete. I believe some of these will fall down, and, in fact, some of them have fallen down. One fell down with an engine on it and they telephoned for me to go out and tell them why it fell down. I told them I didn't need to go out, but reported over the telephone that it was because too heavy an engine was put on top of it.

Mr. Prior: Mr. Lothholz has just finished a highway bridge in this city, the Milwaukee avenue viaduct. Perhaps he has something to say.

Harry C. Lothholz, M. W. S. E.: We had to get up the specifications ourselves to design this bridge. We suggested them to the City and I think they were finally adopted about the way we gave them.

President Reichmann: Was there impact in those bridges, Mr. Lothholz?

Mr. Lothholz: Yes, we used 50% impact.

President Reichmann: How long a span is this?

Mr. Lothholz: We got girders there about 60 ft. long, and 11 ft. deep of reinforced concrete.

William G. Langenheim, M. W. S. E.: What is the cause of impact? In some specifications the apparent reason for considering impact is the speed of the load. The experimentally-proven existence of a critical speed, or, in other words, the fact that the effect of impact does not increase continuously with the load, shows that speed is not the sole cause. The velocity of stress in steel, moreover, is the same as the velocity of sound or other wave propagation through steel, an amount far beyond any speed which either railroad trains or loads of any kind on bridges attain. I believe that pounding is the main cause of impact effects, and that critical speed indicates synchronous vibration.

There is nothing intrinsic in concrete that should make its use on bridges effective against impact stress, except its mass. A study of the resilience of beams shows that a beam heavily loaded is affected to a less degree by an impinging load than when not so loaded. The energy of the impact is expended in moving the larger mass through a smaller distance or deflection, and this deflection is a measure of stress.

The stringers, floor and lateral, add to the actual bottom chords of a bridge, and the absolute amount of increase in stress due to impact would be indicated more clearly on top chords or other members. For this reason top chords and web members are better subjects for stress measurement.

Professor Dufour: I think we can explain that very readily, because of the fact that the reinforced concrete floor distributes the load so that when a load passes over the reinforced-concrete floored bridge it is practically the same as if we took that load—for instance, an 8-ton roller, 16,000 lb.—and distributed it over the entire floor of the bridge; whereas, with a plank-floored bridge it acts almost as if it were a concentrated load. That is indicated by the experiments on the distribution of the load over the floor joists. With plank floor the joists take 88% of the load that comes on it. With reinforced concrete floor, the percentage is very small, and therefore it practically transforms the entire concentrated load into a uniform load. There is no doubt in my mind that Mr. Langenheim is correct in his opinion of the cause of impact. These huge impacts are a result of cumulative synchronous vibration, and it is only when the time of the horse's trot, his footfall, corresponds with the time vibration of the bridge that we get these excessive impact percentages. That is very readily seen, because at 10.2 miles per hour we had ex-

cessive impact; at 10.6 miles per hour the cumulative vibration was broken up and we had very little impact.

In one of the tests that we performed with the farm engine on a reinforced-concrete floored bridge, we took boulders as large as one's hand up to almost the size of two fists, and let the engine run over them. Of course, when the engine wheels would fall over them they would produce excessive impact, but the original stress was so small that even with the excessive impact from rolling over boulders about as large as two fists, it was not large.

It shows that the reinforced concrete floor acts as a part of the lower chord. We would like to have more experiments on upper chords in order to study them and draw conclusions regarding them, but we have not performed those experiments as yet. That is due to several reasons, one being that the men are somewhat afraid to climb around on the upper chord, and I cannot perform all the experiments. The boys who have helped me have done exceedingly well. We hope at a future day to make some experiments with an entire train load of these heavy 13-ton stone wagons, and then we can talk better and more intelligently about our upper chord stresses.

Mr. Lacher: From Professor Dufour's remarks, it was quite clear that the bridges which were tested were bridges of good design, and that the workmanship was such as one would get with a reasonable amount of supervision; in other words, that these bridges represent fairly good specimens of highway bridges, and that the unequal distribution of stresses was, for that reason, rather conservative as compared to what we would expect in bridges that were bought by the span or by the crossing. It would be interesting to know what we would get on some of those bridges.

As to another point mentioned by Professor Dufour: I once had occasion to visit a bridge, while I was with the commission, which illustrated very well the inaccuracy in the fabrication of eye-bars. In some of the chords, if we would strike one bar, it would hum like a piano string, while another would rattle. In fact, a few weeks after the concrete floor had been built an eye-bar in one of the chords failed, transferring the load to the other bar which, to quote Professor Dufour, "had been loafing on the job." Only about a mile from that bridge there was another one which, however, was not under state supervision. The builder had twice attempted to erect the bridge and build the concrete floor, but each time the bridge failed before more than half of the floor had been laid.

I mention this to show that the introduction of the concrete floor has been the source of considerable trouble to the unscrupulous builders, because the concrete floor serves as an actual test load certain to be realized, and which is considerably in excess

of the load to be obtained on a bridge with a wooden floor resulting from the ordinary casual live loads. In consequence, failure to provide adequate design has resulted in the failure of the bridge during the application of the concrete floor rather than at some later date, when the necessary live loading was applied.

Professor Dufour: The reason we have not performed any experiments on the second class of bridges about which we have been hearing is that we are afraid to. All of these bridges, in fact, on which we have performed experiments have been shop-inspected, and most of them have been both shop-inspected and field-inspected. They are a better class of highway bridges. Of course we have some bridges of the other class, but whenever we wanted to test one of those bridges we were confronted by the fact that the man who owned the farm engine or the road roller wanted us to agree to pay for the engine or roller in case it fell through. We did not want to do that, and we could not find anybody who would go across on the roller. We could only experiment on these bridges with a small horse and buggy and that does not indicate much as far as total stress is concerned. We would like to see some experiments performed, but we do not want to do it ourselves.

R. M. Yager, Assoc. W. S. E.: I would ask Professor Dufour if he has made any experiments on panel bridges?

Professor Dufour: We have not yet made any experiments on these, but expect to do so this spring or summer. The reason for that is, there are not many of them near Champaign; but during the last year they have put up some half a dozen riveted pony trusses varying from 50 to 75 ft. in length, with heavy outside brackets at every panel point.

Edwin A. Howes, M. W. S. E.: Were the stresses computed from specified loads or from actual loads?

Professor Dufour: The stresses were computed from the actual loads. It would be interesting to compute them from specified loads, but we have never attempted that. The specified loads are more or less guesswork or approximation, and we thought it would be better to take the scale weights of our various wheel loads.

Mr. Howes: The Sanitary District has built several highway bridges, but none, as yet, with concrete floors. On the Calumet Sag channel, which is now under construction, we expect to build several with concrete floors, but without stringers, only floor beams.

O. F. Dalstrom, M. W. S. E.: On one of the charts there is a critical speed for an automobile. I do not quite see how there can be a critical speed for an automobile unless there are reciprocating parts, because of the synchronous vibration. I would ask Professor Dufour if he can give any explanation of a critical speed for the automobile.

Professor Dufour: That is very easily explained. It was because of the fact that the reinforced concrete bridges had 6 in. of earth on top of them as a cushion, and of course there was some irregularity. There is little doubt in my mind that if the concrete floor were just like a sidewalk there would be no critical speed, but on account of this cushion there were irregularities and the automobile would drop down and jump up, and sometimes jump over them entirely. When it comes to a plank floor, some planks are worn more than others, and occasionally a new plank is put in; therefore the floor is irregular; and when the vibration of the bridge is such that it coincides with the fall of the automobile on one of these planks, we get this result. I do not think there would be much vibration with a smooth floored bridge.

On an interurban bridge we had electric locomotives and the cars themselves—trolley cars—and we ran across the bridge at a speed of nearly 90 miles per hour. We had very little impact, almost nothing at all, just a little wavy line, showing that the loads were perfectly balanced.

PROCEEDINGS OF THE SOCIETY.

MINUTES OF THE MEETINGS.

Regular Meeting, June 2, 1913.

A regular meeting of the Society (No. 827) was held Monday evening, June 2, 1913. The meeting was called to order about 8:30 p. m., Mr. A. Bement presiding, and with about 30 members and guests in attendance. The Secretary reported from the Board of Direction that at their meeting of May 29th the following had applied for admission to the Society:

Linus Cramblet Blackwell, Gary, Ind.
Fred Lamotte, Valparaiso, Ind.
Fred Ruchti, Gary, Ind.
Arthur Caleb Loud, Gary, Ind.
H. D. Oberdorfer, Champaign, Ill.
Charles Hahn, Gary, Ind.
George Buchanan Hoke, Gary, Ind.
George W. Sommerfeld, Gary, Ind.
Edwin B. Styles, Chicago.
Ole Martin Bolme, Gary, Ind.
Clarence J. Kennedy, Gary, Ind.
Edward J. Benjamin, Chicago.
John Croswell Warkley, Gary, Ind.
Pierre Herber, Chicago.
J. Lester Corliss, Chicago.

Also that the following had been elected into the Society:

Henry Olmsted, Jr., Chicago.....	Member
Will Gerald Shurgar, Meridian, Miss.....	Junior Member
Oliver Louis Bear, Chicago.....	Member
Louis George Arnold, Chippewa Falls, Wis., transferred from Junior to.....	Associate Member
Benjamin H. Crosland, Valparaiso, Ind.....	Student Member
Theodore Ray Minert, St. Paul, Minn., transferred from Junior to.....	Associate Member
Louis C. Mory, Lombard, Ill.....	Associate Member
Edmund F. Barkow, Milwaukee, Wis.....	Member

The Chairman then introduced the subject of the evening, "The Adaptation of Boiler Furnaces to Available Coals," by Messrs. Kreisinger and Ray, and asked the Secretary to present some written discussion that had been received. Communications were read from Messrs. E. S. Fessenden, of the University of Wisconsin, R. H. Danforth, of the U. S. Naval Academy, Annapolis, Md., and W. M. Duncan, Alton, Ill. Mr. Kreisinger then presented the paper, in abstract, and discussion followed from the Chairman, and Messrs. W. T. Ray, G. H. Cushing, Osborn Monnett, T. A. Peebles, C. W. Naylor, E. F. Fish (St. Louis), T. A. Marsh and R. H. Kuss, with a closure from the authors of the paper.

Meeting adjourned at 10:50 p. m.

Extra Meeting, June 9, 1913.

An extra meeting of the Society (No. 828), a meeting of the Bridge and Structural Section, was held Monday evening, June 9, 1913. The meeting was called to order at 8:15 p. m., Mr. I. F. Stern, Chairman of the Section, presiding, and with nearly 50 members and guests in attendance. Mr. W. T. Curtis, M. W. S. E., of Detroit, was introduced and read his paper on the reinforcement of the Manistee River Viaduct,—“Doubling the Load Capacity of an Old Iron Railroad Viaduct.” Discussion followed from

Messrs. I. F. Stern, C. M. Pearson, W. H. Kolyn, A. C. Loud, and E. N. Layfield, with a closure from Mr. Curtis.

Meeting adjourned at 10 p. m.

Extra Meeting, June 16, 1913.

An extra meeting of the Society (No. 829) was held Monday evening, June 16, 1913. The meeting was called to order by President Reichmann at 8:20 p. m., with about 50 members and guests in attendance. Mr. J. H. Libberton was introduced, who read the paper, written jointly by C. W. Boynton and himself on "Decorative Possibilities of Concrete." This was illustrated by a large number of beautiful colored lantern slides. There was some discussion from President Reichmann, Mr. Boynton, Mr. Stine-man and a few others.

Meeting adjourned about 9:40 p. m.

Extra Meeting, June 23, 1913.

A special extra meeting of the Society (No. 830) was held Monday evening, June 23, 1913. This was a Ladies' Night.

The meeting was called to order at 8:15 p. m. by President Reichmann with about 150 members and guests in attendance, including many ladies. The President introduced Mr. Wm. H. Shuey, of Oak Park, Ill., who presented "An Amateur Photographer's Story of a Cruise Around the World." This was illustrated by a large number of beautiful stereopticon views, nearly all colored and made by the speaker and in illustration of his "story." Refreshments were served afterwards and the last meeting for this session adjourned about 10:30 p. m.

J. H. WARDER, Secretary.

BOOK REVIEWS.

THESE BOOKS ARE IN THE LIBRARY, W. S. E.

VALUATION OF PUBLIC SERVICE CORPORATIONS, LEGAL AND ECONOMIC PHASES FOR VALUATION FOR RATE MAKING AND PUBLIC PURCHASE. Robert H. Whitten, Ph. D. The Banks Law Publishing Co., New York, 1913. Canvas bound, law book style, 798 pp. 6 by 9 in. Price \$5.50.

The Valuation of Public Utilities is a matter of engineering in its broad sense. The application of the valuation is economic and has opened a new and very useful field of service for the engineers of the country. Because of the newness of this subject, the profession will welcome the book compiled and edited by Dr. Whitten, Librarian for the Public Service Commission for the First District, New York.

This book treats of the legal and economic phases of valuation. It was the aim of the author to present a volume which would embrace the recent and in many instances diverse opinions of expert commissions and courts. This has been done in a logical order and with a fullness of quotation that makes this volume of especial usefulness.

Each chapter is opened with such introduction as may be necessary. In addition the author has given in a summary such conclusions as may be fairly drawn, and while brief they are comprehensively stated. The author recognizes that the conclusions are tentative, until such time as we receive from our Supreme Court a final and authoritative determination, though this may be many years away. The book serves in a satisfactory manner to present as nearly as possible the subject as now understood by the best minds.

The feature of the book which greatly recommends it to the engineer is the fullness and accuracy of quotations. To this is added a Table of Cases cited and a complete Bibliography of Valuation and Depreciation.

June, 1913

The entire production is a credit to the author and will be appreciated by the engineer who has in charge valuation work. E. S. N.

ALTERNATING CURRENT MACHINERY. By Prof. William Esty, S. B., M. A., Lehigh University. From the press of the American School of Correspondence, Chicago, 1912. 467 pp., $6\frac{1}{2}$ by $9\frac{1}{4}$ ins. More than 400 illustrations, half-tone and line engravings. Bound in half leather. Price \$3.00.

This book, or rather treatise, has been written with the special object of presenting a treatment within the comprehension of the practical working man rather than for the trained electrical engineer. The author has accordingly confined himself to the use of simple mathematical formulae, the derivations of which, when given, are made plain and simple by rather full explanations. The treatment does not involve the use of mathematics more advanced than algebra and simple trigonometry, and, whenever possible, graphical and vectorial methods have been used in preference to analytical or algebraic discussions. Numerous examples with their solutions are used to illustrate the mathematical discussions and formulae.

Nearly 60 pages have been devoted to a very full but simplified discussion of the elementary principles of alternating current and a comparison of alternating and direct current phenomena.

The book treats quite fully of the principles of Alternating Current; Alternating Current Generators, with description and illustrations of the common types now being manufactured and those manufactured during the last 10 or 12 years and still in commercial use; Synchronous Motors; Transformers; Rotary Converters; Motor Generators; Induction Motors; Switchboards; Switch-gear; Lightning-Arrestors, and a short appendix of five pages on the subject of Operation of Alternators. Considering the importance of this last named subject, it is to be regretted that it did not receive a longer treatment.

The book is very freely illustrated with circuit diagrams, cuts and geometric figures.

The general arrangement of the text and mathematical discussion renders it more suitable as a text-book than as a work of reference, and it is evident that this has been the author's intention.

There is required of the reader a working knowledge of the elementary laws of electricity and magnetism and a moderately good knowledge of algebra, geometry and elementary trigonometry, to get the best results from this book. E. F. B.

THE PORT OF HAMBURG, (GERMANY), by Edwin J. Clapp. Yale University Press, New Haven, Conn., 1911. 220 pages, 8 by $5\frac{1}{2}$ in. Cloth bound. Price \$1.50.

This is an admirable book of great general interest and especially so to those interested in transportation, commerce, and in harbor matters. The author conceived that the modernization of terminals for ocean and lake commerce should be along the lines followed by Hamburg. Much has been said and written about the cheapness of water transportation, yet if we in this country desire to resuscitate the decadent river transportation, it must be modeled after what has proved so successful on the great German rivers, as the Elbe and the Rhine. The author does not attempt to show or lay down a program for our guidance, but shows what has been done in Europe. He has made a careful study of what has been done abroad, which is a necessary preliminary to the preparation of any practicable program. A very fair map of the transportation lines of Germany, showing the main lines of the railroads, the canals built and being built, and the river systems with the cities of Germany, at the beginning of the book, is of value for ready reference, in reading the text.

The book opens with an introduction concerning the nature of a great seaport. Chapter I relates to the development of Hamburg's Hinterland, which has had a great influence on the development of this very important port. The Channel to the Sea is the subject of Chapter II, and the next chapter tells of the Port Facilities, which must be extensive and commensurate to the business to be done. Among these are the various devices to assist the rapid loading or unloading of the vessels in the harbor. With the great value of the big trans-Atlantic lines, with their heavy overhead charges, due to their cost and maintenance, it is an essential in order to secure profits, that the time the ship is in port, unloading or taking on cargo, and during which time the boat is not earning anything, that this time be reduced to a minimum.

In Chapter IV, the Hamburg Over-sea lines are described with a good deal of statistics relevant thereto, and this is naturally followed by Chapter V on Hamburg's ship builders and merchants, with state aid to the Merchant Marine. The inter-relation of waterways and railways, particularly in Germany, is the subject of Chapter VI, in which the author shows clearly, the conditions at the Port of Hamburg and how these conditions, properly fostered and developed have contributed so much to the growth of that port.

Chapters VII and VIII conclude this interesting work and these treat of shipping and commerce in Hamburg, 1907, and Hamburg's commerce with its Hinterland. The book is illustrated with a score of halftone illustrations, and at the end is a comprehensive map of Hamburg showing the several harbors and slips with piers between them carrying railroad lines, warehouses, etc., so essential to the commerce of a great port.

There is a Bibliography of over 3 pages, (49 notations), but which are mostly of German origin, only 6 of these notices being in English. A rather copious index, concludes the book. "The volume is full of matter of vital import to those interested in our railroads and in our ocean, great lakes and river terminals."

LIBRARY NOTES.

The Library Committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts, the following publications have been received:

MISCELLANEOUS GIFTS.

P. Blakiston's Son & Co.:

The Examination of Water and Water Supplies, John C. Thresh. Cloth.

American Institute of Consulting Engineers:

Expert Evidence, A Discussion at Meeting of October 25, 1912. Pam.

New York State Department of Health:

Report on the Application of Ozone to Water Purification. Folio.

EXCHANGES.

National Electric Lamp Association:

Abstract Bulletin of Laboratory of the N. E. L. A., Jan., 1913. Pam.

American Railway Engineering Association:

Proceedings, 1905, 1909, 1913. 3 cloth. Cloth.

Ontario Hydro-Electric Power Commission:

Annual Reports Nos. 1-5. Pams.

Liverpool Engineering Society:

Transactions, 1912. Paper.

June, 1913

- Institution of Water Engineers, London:
Transactions, 1912. Cloth.
- American Institute of Mining Engineers:
Transactions, 1912. Paper.
- University of Illinois Engineering Experiment Station:
Bulletins Nos. 55, 56. Pams.
- Illinois State Penitentiary:
Report of Commissioners for two years ending September 30, 1912.
Cloth.
- West Virginia Geological Survey:
Volume V (a) 1913, Living Flora, Fossil Flora. Cloth.
Map Showing Oil, Gas, Iron Ore, and Limestone Areas.
- Canada Department of Mines:
Annual Report of Mineral Production of Canada, 1911. Paper.
The Magnetic Iron Sands of Nataskwan, Quebec. Pam.
- Institution of Mechanical Engineers, London:
Proceedings, October-December, 1912. Paper.
List of Members, 1913. Paper.
- Engineering Society of York, Pa.:
Proceedings, 1913. Pam.
- Illinois Society of Engineers and Surveyors:
Proceedings 28th Annual Meeting, 1913. Paper.

GOVERNMENT PUBLICATIONS.

- U. S. Bureau of Mines:
Report of Mine Inspector for Territory of Alaska, 1912. Pam.
Technical Papers Nos. 14, 46, 52, 53, Pams.
- U. S. Department of Commerce:
General Rules and Regulations Prescribed by the Board of Super-
vising Inspectors. Pam.
- U. S. Bureau of Standards:
Bulletins, Vol. VIII, No. 4; Vol. IX, No. 1. 2 pams.
Technologic Papers Nos. 12, 13. Pams.
- U. S. Geological Survey:
The Production of Bauxite and Aluminum in 1912. Pam.
The Production of Fluorspar and Cryolite in 1912. Pam.
The Production of Anthracite in 1912. Pam.
Statistics of the Pottery Industry in the United States in 1912.
Pam.
- U. S. Coast and Geodetic Survey:
Determination of Time, Longitude, Latitude, and Azimuth. Paper.
Quarto.
- U. S. Bureau of the Census:
Abstract, with Supplements for Illinois, Indiana, Iowa, Michigan,
Missouri, Wisconsin. 6 vols. Quarto. Cloth.

MEMBERSHIP.

Additions.

- Arnold, Louis G., Chippewa Falls, Wis., transferred
from Junior to Associate Member
- Barkow, Edmund F., Milwaukee, Wis. Member
- Bear, Oliver L., Chicago. Member
- Crosland, Benjamin H., Valparaiso, Ind. Student Member
- Minert, Theodore R., St. Paul, Minn., transferred from
Junior to Associate Member
- Mory, Louis C., Lombard, Ill. Associate Member
- Olmsted, Henry, Jr., Chicago Member
- Shurgar, Will G., Meridian, Miss. Junior Member

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No. 7

A SUGGESTED METHOD OF PREVENTING ROCK SLIDES

GEORGE S. RICE, M. W. S. E.

Presented May 12, 1913.

Earth and rock lateral movements and slides, have always been matters of serious concern in engineering undertakings, both in surface construction and in underground mining. The writer, as a mining engineer, has been concerned chiefly with the underground movement. Sometimes the underground movement most seriously affects the surface, as for example when coal or ore has been removed from an area, and the roof has caved all the way to the surface either immediately or subsequently. In many instances the subsidence is very great, wrecking surface improvements, and sometimes, in hilly or mountainous country, causing land or rock slides.

TURTLE MOUNTAIN SLIDE.

A striking instance of the latter is the Turtle Mountain slide, in Frank, Alberta, which occurred in 1903, causing the loss of 70 lives, and destroying half of the property of that town. At a later period further slides from this mountain were threatened, and the writer served on a Canadian Commission, convened in 1911, to determine whether or not the mining in a coal bed at the foot of the mountain had been influential in causing the first slide, and whether a continuance of mining operations was likely to cause further slides that would endanger the remaining portion of the town. The accompanying profiles and pictures (Figures 1, 2, 3, 4 and Plate I) show the interesting situation. In the case of the first slide it was thought by the Commission that the coal mining had probably been the immediate cause of setting in motion a naturally unstable rock mass. The only safeguard, if the mining was to be continued in the danger zone, was, in the opinion of the Commission, to pack tightly the mine workings so there would be practically no subsidence. But, as such packing did not appear commercially feasible, they recommended that the town be moved. It was decided by the Dominion of Canada to expropriate the town site and move the houses. The bearing in the present discussion is to indicate the possibility of an unstable mountain mass being set in motion by a very small movement at its base. Once started, such a mass is irresistible as far as man's efforts are concerned; but the first movement may

be prevented by a relatively weak support, which in the case of Turtle Mountain was represented by a strip of coal immediately along the out-crop. In the limits of this brief paper it is impossible to go into the many studies that have been made as to the angles of repose of different natural materials. In the case of Turtle Mountain, the angle of the superficial rock slides is 30° , but this by no means indicates what may be the angle of the slope on which a great mass may start to slide. The Turtle Mountain formation for the most part is made up of massive rock (chiefly limestone, see Fig. 4), so that the angle of sliding is steep. On the other hand, a loosely coherent material, such as is met with in the Culebra Cut of the Panama Canal, when water-soaked, undoubtedly would move on a



Fig. 1. Turtle Mountain Slide.—Frank, Alberta.

much lower slope. Much the same problem is met with in mining, where such systems of mining are employed as involve the removal of pillars or the leaving of large areas unsupported.

An allied problem involves the stability of natural strata, that is, the angle at which they will stand. In this the question of crushing is involved. For example, a strong stratum of rock, like limestone or granite, may stand vertically, or even overhang for great heights, but when the wall of rock is thousands of feet high, the pressure may be sufficiently great at the base to crush the rock along the unsupported face. When the strata have little strength, the bottom layers may squeeze or flow out, dislodging the mass

above. Such conditions constantly occur in the deep open pits of the iron mines of the Lake Superior district. The problem, when the strata rest on a sloping sub-stratum, is manifestly closely connected with the question of the angle of slope on which the material may slide. It is further complicated by the presence of rock joints and fault lines, if there be such, so that what first concerns only the crushing strength of the lower stratum may subsequently involve questions of sliding. The lateral movement once started, the vertical pressure of the material back from the open face may, through a curved path, be converted into a horizontal pressure.

Another phase of the problem, the flow of a soft stratum like a shale under great pressure, is strikingly exemplified in mines



Fig. 2. Fissures in Turtle Mountain caused by pull of middle peak (which formerly stood beyond it) when it slid down in 1903.

where there is a clay or shale floor. When the pillars are overloaded, the clay or shale is squeezed up into the entries or excavations. A "heaving bottom" is a common experience in coal mines; even in the stronger strata, such as are found in the Lake Superior copper mines, the weight on the foot wall may be so great as to cause it to bulge up into the excavations. The action is of course intensified where water enters the rock joints bearing clayey materials, which form planes on which sliding may take place.

PANAMA CANAL.

In the Culebra Cut of the Panama Canal (see Plate III showing section along Culebra Cut), as is well known, most serious difficulties were encountered in the fall of 1913. September, 1913.

ties are being experienced from the great slides which are taking place from the sides of the cut. The writer has not been fortunate enough to visit the Panama Canal, and the information he has received regarding it has come from visiting engineers, and from the annual reports of the Isthmian Canal Commission. The report of 1912 contains an interesting description of the geological formation and the cause of slides, by the geologist, Mr. Donald F. MacDonald. A brief summary of his findings, is as follows:

The Land Slides of Culebra Cut: The slides up to September 14, 1912, have added several million cubic yards to the original estimates for the excavation of Culebra Cut, and Mr. MacDonald thinks that before the sliding period is ended the estimates will have to be swelled several million yards additional.

Geological Conditions: The oldest rocks exposed along the

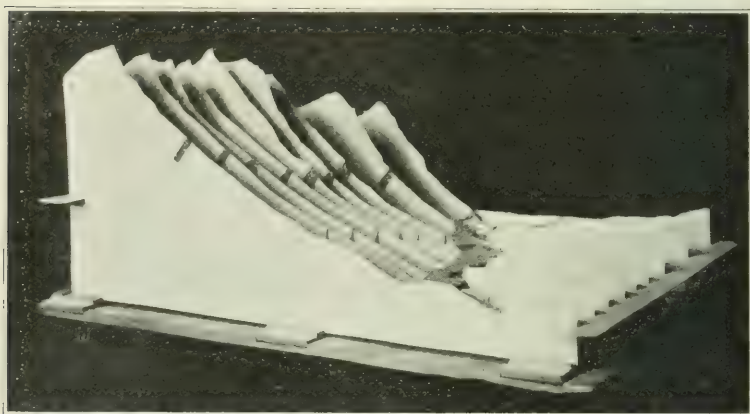


Fig. 3. Working Model of Vertical Sections of Turtle Mountain, Alberta, Used by the 1911 Commission in Studying the Possibility of Further Sliding. The Sixth, Seventh and Eighth Sections (from right) Indicate the Area on Which the 1903 Slide Took Place.

canal consist of a series of volcanic rocks much faulted. These are covered by land deposits of volcanic origin into which there have been later volcanic intrusions. Following this the land sunk below sea level and sediments were deposited, resulting in the formation of sandstone, limestone and shale; deposits of pyrite occurring locally. Accompanying or following the subsequent elevation, further volcanic intrusions occurred, causing the sedimentary strata to become greatly crushed and faulted. The main volcanic stocks or masses, such as form the core of Contractor's Hill and Zion Hill, are stable. The faults caused by the volcanic intrusions are lines of weakness and cut diagonally across the canal.

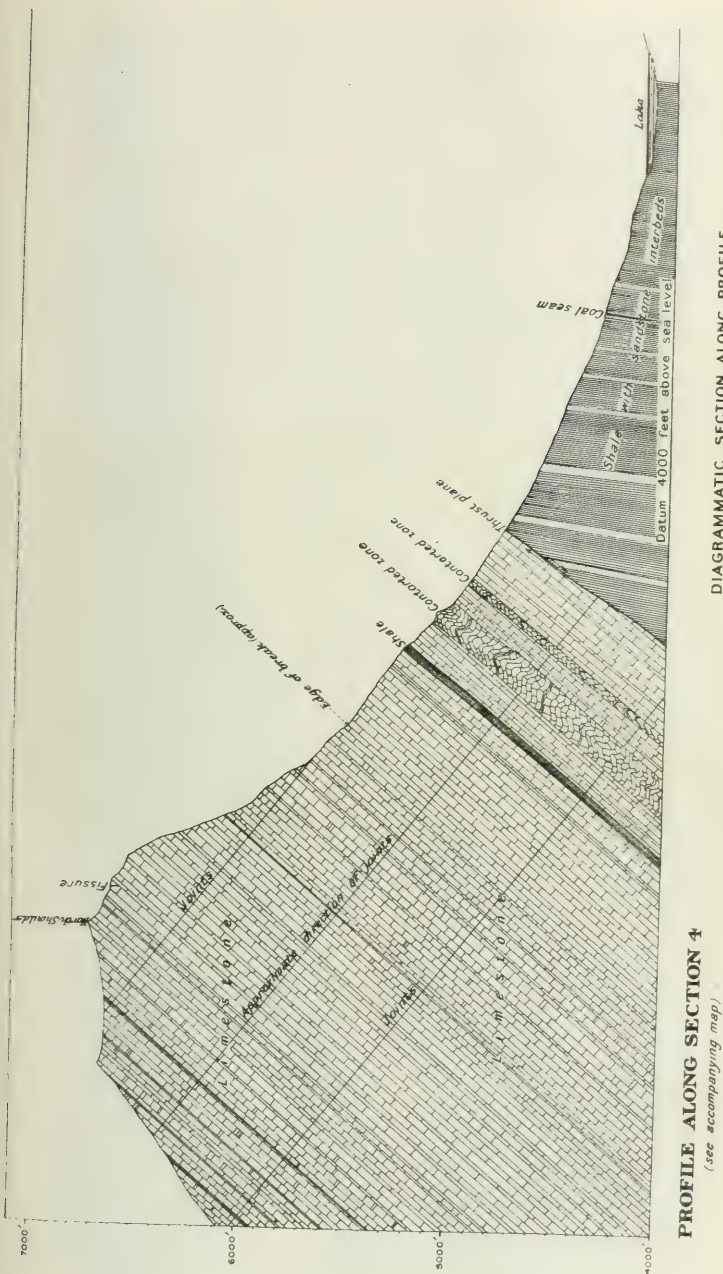


Fig. 4. Geologic Structure of Turtle Mountain, Alberta.

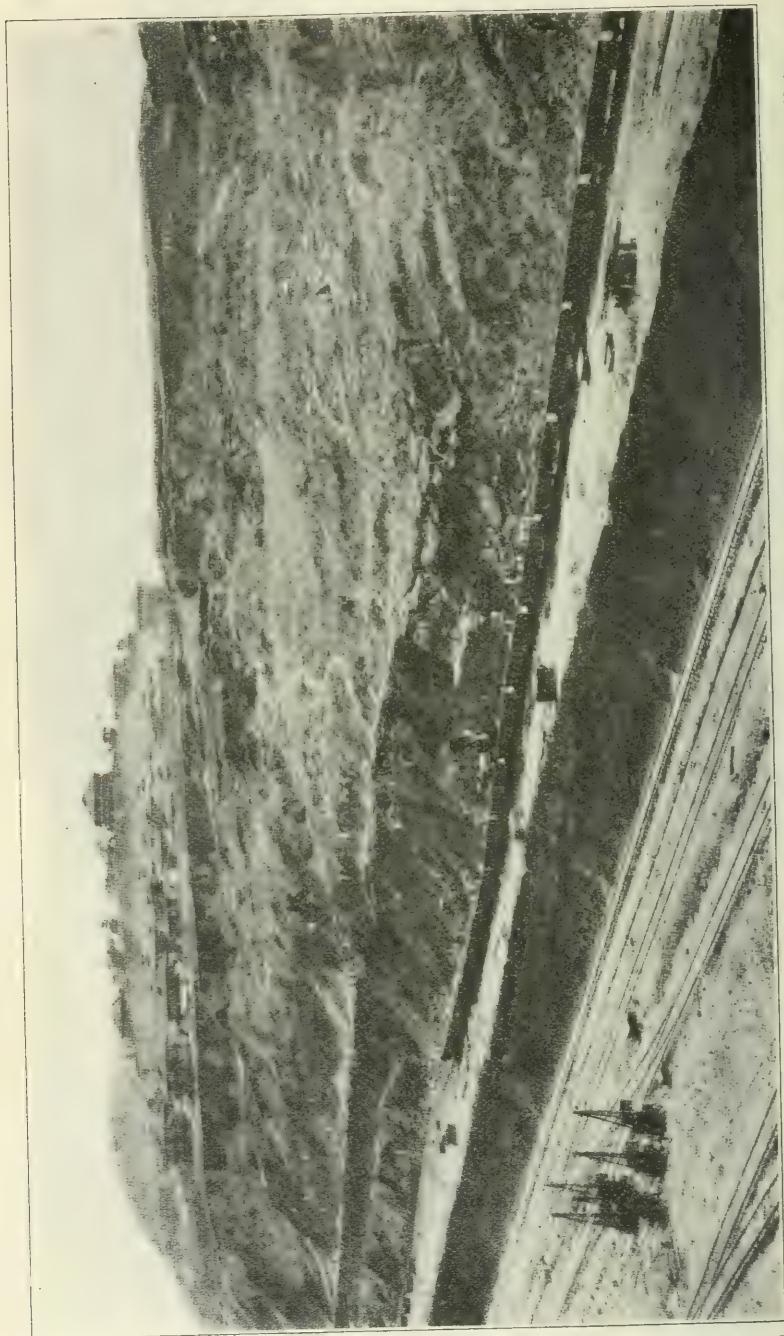


Fig. 5. Slide of Stratified Rock, West Bank of Canal, Culebra. On-the-Dump, Looking Toward Culebra, February, 1912. Slide Involves About One Million Cubic Yards Which Moved About Three Feet Daily on a Slope of One Vertical to Seven Horizontal. The Train is Standing at Elevation + 95.

Types of Slides: Mr. MacDonald classifies four types of slides:

- "(1) Structural breaks and deformations resulting in slides.
- "(2) Normal or gravity slides.
- "(3) Fault-zone slides.
- "(4) Weather and surface erosion."

(1) *Structural Break and Deformative Slides:* This type Mr. MacDonald says "is by far the most troublesome, as well as the most important." "The first manifestation of these slides is the appearance of fissures parallel or oblique to the edge of the slope of Culebra Cut, a few yards to a hundred or more yards back of it. They can be followed on the surface for several hundred yards and gradually widen out to form perpendicular crevasses several inches wide." "The second stage of this type of slide consists of a canal-ward tilting of the blocks, usually accompanied by a deformation or bulging up of the rocks in the bottom of the canal opposite them. * * * The last stage consists in the dropping downward of one or more blocks, due to the failure and squashing out of the basal part of each. Then the whole block disintegrates and soon becomes a normal gravity earth-rock slide piling up at the bottom of the cut." (See Figs. 5, 6 and 7, also Plate II.) Mr. MacDonald considers that there is only one remedy, to make the slopes less steep "by removing material from their upper portions, so that the unbalanced pressure toward the foot of the steep high cut banks shall be less than the crushing strength of the rocks involved."

The question raised by the writer of this paper is whether the pressure at the foot cannot be balanced by the suggested type of underground retaining wall.

(2) *Normal or Gravity Slides:* "Locally along Culebra Cut porous material lies on top of relatively impervious clay." The rain water saturates the porous material along which the material slides. Mr. MacDonald considers that no saving of excavation could be accomplished by removing the material from the top part. He states that this type of slide was troublesome a few years ago, but is not now of importance.

(3) *Fault Zone Slides:* These are due to faults (see cross-section, Fig. 7) in some places having weakened the rock, and owing to the acute angle between the fault planes and the axis of the canal where the slopes are steep, slides occur. Mr. MacDonald states that fortunately these are not common as it would be difficult to apply remedies.

(4) *Sliding Ground Due to Weathering and Erosion:* Mr. MacDonald thinks that these superficial slides or "wash" will be taken care of by promoting the growth of vegetation on the slopes.

Erosion From Canal Water Waves: Mr. MacDonald points out that on completion of the canal another serious matter is the



Fig. 6. Rock Slide at Panama Canal Burying a Steam Shovel. West Side of Canal Near Las Cascadas. This Shovel Was Working on the Bottom of the Canal When Destroyed, May 31, 1912.

erosion problem along the water's edge resulting from the "wash" of steamers going through the canal. Some of the constituents of the rocks are more or less soluble, and unless some protection is given there will be trouble from this source. He thinks that no system of retaining walls will prevent large slides, but that there should be a protecting revetment along the water's edge where the rocks are crumbly. A thin coating of cement was spread on the slopes by a "cement gun," but due to the swelling nature of the rock and vibration from blasting, in a few months the coating began to peel off.

Mr. MacDonald believes the counterbalancing effect of the water against the slopes of the canal will be very small so far as the slides are concerned, for the following reasons: "The sliding material has an average specific gravity of about 2.5, hence 45 ft. of water would balance about 18 ft. of slide if the pressures were evenly distributed. Considering the more or less wedge-shaped fronts and the back pressures of many of the slides, it is estimated that the 45 ft. of water would be equivalent to about 10 ft. of slide pressure. Other considerations are that, though the water will protect the lower part of the canal from oxidation and weathering, it will cause the water to permeate, under pressure, the cracks and interstices at the foot of the slope."

The conclusion that the writer has reached after studying Mr. MacDonald's report and the statements of others is, that the slides may continue to be a serious matter for a long time to come, even after the opening of the canal; therefore it will be advisable to give the fullest consideration to any methods or plans which will tend to insure prevention of slides. A certain process used in shaft sinking and tunnel work suggested to the writer, in combination with other ideas, a possible method of erecting an underground retaining wall which, while not feasible to apply to ground in motion, will perhaps prevent the formation of a slide in threatening ground by taking care of the unbalanced pressures due to deep excavation.

SHAFT SINKING CEMENTATION PROCESS.

While the method of filling cavities and rock crevices behind tunnel linings, with cement grouting, has long been employed, a special application called the cementation process, which has been highly developed in northern France for sinking through porous and creviced, water-bearing strata, presents important features. Briefly, it consists of drilling a series of holes surrounding the shaft location through the porous strata to the more or less impervious coal measures, pumping in cement grouting under high pressure, either continuously as the drilling proceeds, or, as in later undertakings was found to be better, in stages at intervals alternating with drilling every 16 ft. By this method a cylinder of cemented strata is constructed around the shaft location so that the shaft can

be sunk with little or no leakage of water. In the earlier undertakings four drill holes were used, but for the later shaft sinkings six holes were employed in a circle with a diameter of 24 ft.

To prevent leakage to the surface of the injected grouting, a pit (see Fig. 8), is first dug for each bore hole through the loose earth and concrete placed tightly about a 12 in. standpipe, the top of which is capped. The cap has a stuffing box, through which passes a grouting pipe that can be pushed through to near the bottom of the hole at the time the injection of cement begins. The grouting pipe is connected with the pump, and the latter with the cement mixer. There is a side opening at the top of the casing with pressure gauge and valve. Before injection of cement begins, clear water is pumped through to clean out the mud; then the side opening is connected with a pipe to the cement mixer to send back surplus cement when the ground will take no more at the pressure employed.

It has been found necessary to use only the finest ground cement, and employ pressures as high as 750 lb. per sq. in. to insure the thorough permeation of the cement into the small crevices and bedding planes of the strata. On this account the removal of all mud coating from the walls of the bore hole is found necessary; to this end it is the practice to drill the hole below the standpipe, about 7 in. in diameter, and then ream to 10 in.

The water-bearing strata consist of marls, or fissured chinks which are sometimes argillaceous. They are soft enough to be bored with an auger drill turned by power. The process has been so successful that it is supplanting the freezing system for sinking through highly water-bearing strata in northern France and Belgium.*

PROPOSED SCHEME OF CONSTRUCTING UNDERGROUND RETAINING WALLS.

The success achieved in cementing porous, creviced strata appeared to the writer to offer possibilities in solidifying the slopes of unstable strata, at least sufficiently to prevent movement from occurring under many conditions (of course not all) that now give trouble. The holes themselves, when filled with concrete, reinforced with iron bars, have all the advantages of deep seated massive piles. It then came to mind, why not extend this principle and drill inclined holes to solid strata with diamond or auger drills, and insert in them heavy reinforcing bars which, when surrounded with cement, would act as diagonals or tension members?

A further development suggested by mining practice was to "spring" the holes at the bottom by shooting with dynamite. This would have two advantageous results,—it would open up crevices, permitting a more extensive cementation, and would provide an

*An excellent description of the method is given in a bulletin of the Société de L'Industrie Minérale, 1908, entitled "Cementation des Terres Aquifères," by J. Lombois.

enlargement which would furnish anchorage in deep firm strata for the tie bars. The upper end of the tie bar is to be held by a concrete capping. Thus the combination of vertical concrete posts and metal ties, going deep enough to reach solid strata, with the ground cemented between, would furnish a triangular dam, or retaining wall. This, if seated in solid formation, should have great strength against lateral pressure. A great merit would be in the ability to concentrate tie bars as much as desired. The nearer the holes, the more thorough would be the cementation. The only limit would be that of cost. See Figs. 9 and 10.

Necessarily the system, if applied extensively, would be costly; on the other hand, it would only be considered where the cost of repairing damage to an engineering work by an extensive land slide would be vastly greater.

Under the conditions that obtain in northern France, the cementation of one shaft to a depth of 341 ft. cost in labor, \$6,400; in material, \$6,800; a total of \$13,200, or \$39.00 per linear foot. The diameter of the cemented cylinder probably exceeded 40 ft. If this assumption is correct, the cementation costs about 84c per cu. yd. of cemented ground.

Ordinary retaining walls to be held by tie rods: An opportunity for application of the scheme of using tie rods cemented in drill holes and anchored in solid formation, is found in the holding in place of ordinary retaining walls. Inclined holes may be bored into the retained bank to sufficient depth to obtain anchorage in firm ground; then a charge of dynamite would be exploded in the back of each hole to enlarge it. After putting the tie rod in place, liquid cement would be poured in until the hole is filled. Each end of the tie rod should be "upset" or have suitable nuts and washers. The outer end would be built into the wall, which, if of concrete, can be made relatively light, as the tie rods should be made to take care of the overturning stresses. The adoption of such a system would make a radical change in the design of ordinary retaining walls relying on gravity to prevent overturning.

SLIDES IN CULEBRA CUT—PANAMA CANAL.

In the matter of slides in the Culebra Cut of the Panama Canal, many engineers seem to feel that it is only a question of keeping on digging out the slide material which comes down. This, of course, can be done, but there is always the liability that a sudden slide may block the canal or even catch vessels, since the movement of the slides is sometimes very rapid, as shown by the burying of a steam shovel (Fig. 6). Furthermore, as is indicated by the cross section of the canal (Plate II), the low slope on which the slides run is surprising, so that the volume of material which may come into the canal is tremendous. This, in itself, is a good reason why everything should be done, even at considerable immediate cost, to prevent them from occurring, because, as the canal

geologist points out, when one slide has occurred it leaves a steep face, which being unsupported may allow another slide to follow.

OUTLINE OF PROPOSED PLAN OF PREVENTING SLIDES:

The writer, in proposing a scheme for checking, or rather preventing slides from occurring, has had three main thoughts in mind: *First*, that as far as possible there be drainage. *Second*, that there should be a sub-division of the slopes from which the slides are liable to come. *Third*, the interposition of what may be

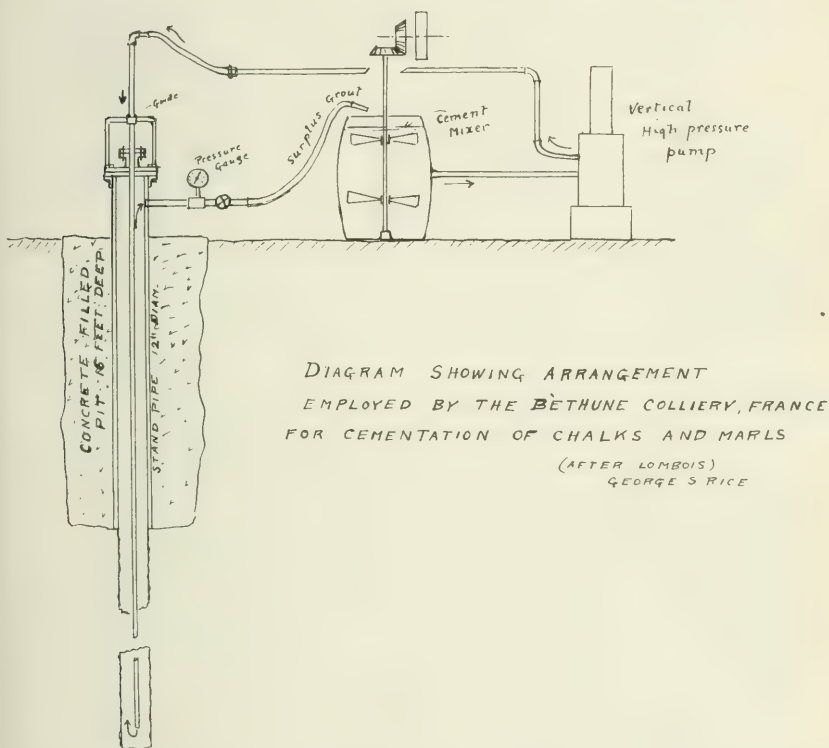


Fig. 8. Sketch of Apparatus Employed in Europe for Cementation of Shafts in Waterbearing Situations.

termed an underground dam, to prevent the foot of a slope or side wall from moving, and also to keep the water of the canal from circulating through the sidewalls. The term "circulating" is used advisedly, as it would appear to the writer that it is very much more destructive to the somewhat soluble walls to have fresh water constantly entering the pores and crevices through wave action, and again being drawn off, than if the ground water is merely held quiescent.

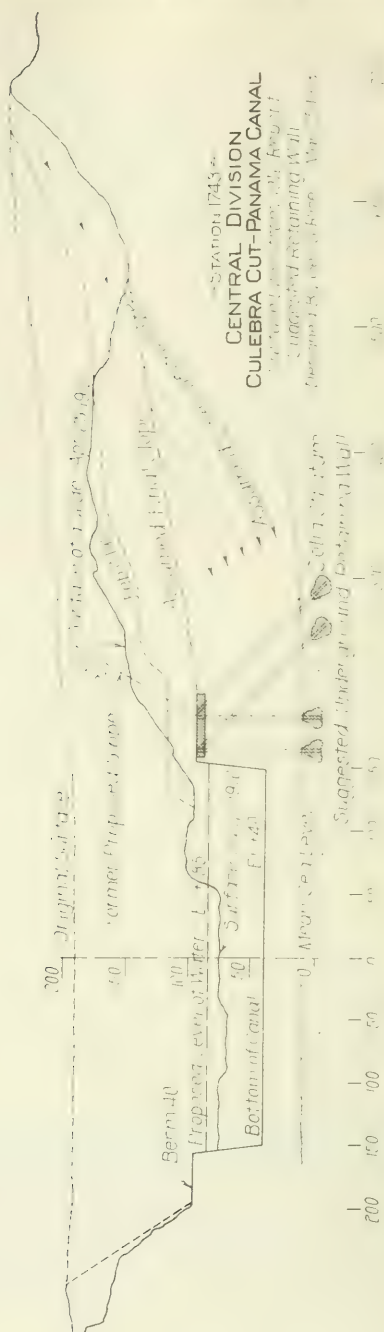


Fig. 9. Sketch Showing Suggested Application at Panama Canal of Underground Retaining Wall. Plotted on a Section of a Typical Slide.

The purpose of preventing a small movement in the foot of a slope is well indicated by the fearful results following only a few feet of movement at the base of Turtle Mountain, which probably led to the dislodgment of a mass of material estimated to contain 45,000,000 tons, and which moved on a slope of about 30° . It is also interesting to note that in the original plan for Culebra Cut the proposed slopes were made 60° , which is much steeper than the slope on which the relatively strong, though fractured rock in Turtle Mountain would remain stable. The average slope of the slide areas in the Culebra Cut is surprisingly low,—in some cases as low as 1 to 8 or 10. (See Plate II.)

DETAILS OF PROPOSED PLAN OF PREVENTING SLIDES:

The scheme is:

(1) To drill a series of holes placed along lines parallel with the axis of the canal, these holes to be both vertical and inclined, and go deep enough to reach firm strata below the level of the bottom of the canal. The depth of the holes might need to be 100 ft. or perhaps over 150 ft. deep. (See Fig. 9.)

(2) Cement grouting is to be forced into these holes under high pressure, 750 to 1,000 lb. per sq. in., by the method previously described, so that the cement will penetrate all the joints and fissures, making the mass impervious to water, and also binding the rock together.

(3) Steel rods are to be placed in the holes; these rods may be of considerable diameter, say 3 in. or more, and are to be grouted into the holes.

(4) Before the steel bars have been placed in the holes, dynamite is to be fired in the bottom of each hole to make an enlarged or pear-shaped space in the firm stratum which the holes should reach. These, when filled with cement grouting, will provide anchorage at the bottom. The rods will thus act as reinforcement in the cemented zone; and the rods in the inclined holes will serve as tension members of the wall. The latter rods will therefore be made much heavier than the others—the size being proportioned to the probable stress, so far as can be estimated. The rods are to have nuts and washers or to be "upset" at each end. The upper ends are to be fastened in a concrete capping over the top of the "dam."

This underground dam or buttress will be of approximately triangular shape, the base being at the bottom, and deep enough to be in firm strata. The vertical holes would be drilled by ordinary churn or auger drills. The diagonal holes to be drilled with either a diamond or chilled shot drill, or auger if the strata are not too hard.

In applying this method for the support of side walls of the Panama Canal or elsewhere, it must be done before the ground begins to move. It is evident that it cannot be applied to ground that is actually moving. Moreover, the wall must go sufficiently

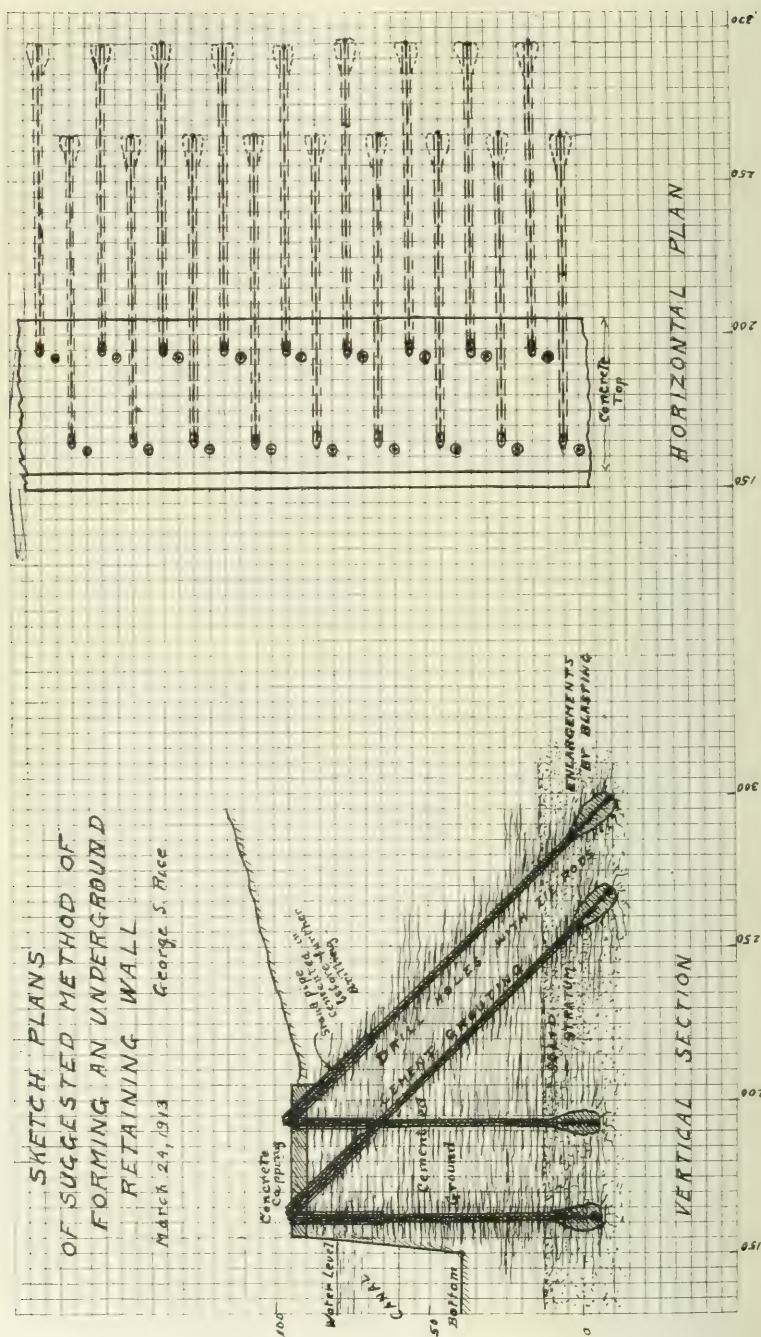


Fig. 10. Sketch Showing Proposed Underground Retaining Wall.

deep to get into solid strata; but there is nothing but cost to prevent such an underground dam from going as deep as seems desirable, or to make the holes as large or the tie rods as heavy as desired. It must be admitted that the expense of application is very great, but on the other hand the saving that might be effected may be vastly greater, besides insuring that the finished engineering work is reasonably certain to be stable. It would of course be a desirable thing to try out the method beyond the present slide areas in order to determine the obstacles and necessities of the case. The work could be pushed from either edge into the slide area. Intermediate ground walls could be constructed further up the slopes, so as to lessen the weight and also to prevent water which might enter above from working down into the larger mass below. Accompanying these dams, underground horizontal drifts might in some cases be put into the slopes to drain the ground.

In order to obtain information about the stresses, a trial dam might be built ahead of a slow moving slide. In the same bore hole in which a tie rod was placed, a small rod (say $\frac{1}{4}$ in.) inclosed in a pipe, could be inserted parallel to it, the rod to be greased so as to allow free play in the pipe. Before inserting the rods into the bore hole, the small rod could be attached to the tie rod at the lower end or intermediate point, as desired, and extended to the surface parallel with the main rod. The extension of the main rod could then be measured by comparison with the $\frac{1}{4}$ in. rod, which would not be put under stress, although the small inclosing pipe might pull apart at the joints.

In conclusion, while it is evident that the scheme of the underground retaining wall cannot be applied to all natural conditions, apart from the limitation of cost, it is hoped by the writer that in some cases it will be advantageous. So far as the writer knows the plan of combining steel or iron reinforcement with underground cementation is new. The features of providing tension members of calculable stress, and their anchorage by enlarging the bottom of the holes and filling with cement around the tie rods, appears to be new.

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DISCUSSION.

I. F. Stern, Chairman: We feel very grateful to Mr. Rice for the able and interesting paper he has presented, as it brought a certain new message or idea. The subject is now open for discussion.

A. A. Schenck, M. W. S. E.: The author very properly makes the distinction between angle of repose of a material and what may be called the "sliding angle," on which a mass as a whole may slide. The latter angle may be small, depending, of course, on the friction at the base of the mass. Several railroads have been subjected to great expense and delays from ignoring the difference between angle of repose of a material and the sliding angle. On the West Shore

Road, when I took charge from Newburgh to south of West Point, the construction was almost at a standstill for this reason. The angle of repose of excavated rock had been carefully noted, the sections of desired embankments had been carefully computed. It was assumed that if an amount of excavated rock so computed were taken from the rock cuts and placed in the embankments, the work must necessarily progress to completion.

The bottom of the Hudson river was hard mud on a 20° slope, running down to 300 ft. depth of water. When I took charge, numerous portions of numerous embankments were promptly side-stepping and seeking lower locations. The engineer in general charge under the Chief Engineer, one of our best mathematicians in the engineering service, was positive, with a goodly array of figures, that the work was mathematically correct and must go ahead as projected. Acting under special instructions from the Chief Engineer, I was obliged to throw the line sharply inward into the cut at numerous places, and in three cases, to introduce long steel spans across indentations of the cliffs, to avoid placing fills on the slippery underwater slopes. A condition made with the German bondholders prevented the introduction of tunnels.

When I took charge, by direction of Mr. Villard, as Resident Engineer of the operated lines of the Oregon Railway and Navigation Company in 1883, under Chief Engineer Thielsen, the first work put in my hands by the General Manager was to stop the movement of the sliding ground at Cascade Locks. When it comes to wanting things our higher railway officers sometimes assume that the engineer is something of a demigod in control of nature. This sliding ground at Cascade Locks was the sliding side of a mountain, from a line many hundred feet above the railway track, which was itself perhaps 50 ft. above the Columbia River. The slide showed how a very small defect may start something beyond human control. In general, such a slope (or talus) at the base of higher ground in time becomes coated with a waterproof covering of turf or other material. When a small crack is caused, perhaps at a great distance by reason of an excavation, surface water gets in the crack. This water lubricates the sloping hard underlying material on which the sliding material rests. Frost aids the action. As the slide progresses, the cracks become larger, and more surface water gets in. Ultimately it is a case of attempting to oppose hydraulic mining of huge dimensions. At Cascade Locks immense blocks of overlying material, many feet in dimension each way, were mingled with deep fissures several feet wide and of great depth. When a large mass, many hundred feet in each direction and several hundred feet deep, becomes so broken, and rests upon a hard inclined surface made slippery by surface water, there is no resource except to continue excavating as the material gradually (or otherwise) comes down. It is generally almost impossible to make an artificial waterproof surface, and keep out the surface water. No construction could oppose weight suffi-

cient to secure a stoppage of the sliding movement. It is necessary simply to take the medicine and continue "maintenance" in the way of removing what fate sends to us.

At long range, many of us are wondering what else can be done at the Culebra Cut of the Panama Canal.

Hiram J. Slifer, M. W. S. E.: I am a great believer in the fact that the civil engineering profession can do almost anything. There are only a few things that are impossible to it, but there are many things that are impracticable. In my experience as a civil engineer I have had some experiences similar to those of Mr. Schenck, where I have been compelled to simply fight the conditions and keep on fighting them.

This subject is one in which I have been much interested, both as an engineer and as an operating officer, and also as a member of committees of various engineering societies.

I divide slides into two different general subjects or heads—slides which are due to excavations, and slides which are due to embankments. I take the general position that there are no two slides alike in their character. That decision is based on my experience.

After spending more than twenty years in the engineering profession and as an operating officer of railroads, I was called to the Isthmus of Panama. After I had been there some few months the Roadway Committee of the American Railway Engineering Association sent me their advanced report, particularly as it applied to slides. I wrote back to the chairman of the committee, Mr. Bremner, of the Chicago, Burlington & Quincy R. R. Co., telling him that after looking around over the Isthmus the few months I had been there I concluded I was an infant on the subject and therefore did not care to express my opinion.

My first experience with this matter of slides was when I was connected with the Pennsylvania Railroad around the city of Philadelphia some thirty years ago, when it was decided that we would sod the various cuts to keep them from sliding. Under the direction of the Chief Engineer, Mr. W. H. Brown, we made quite a study of the subject in the office of the Engineer of Maintenance of Way, with which office I was connected. I went to the Franklin Institute and had one of my French friends read me what the French people had been doing in connection with the slide question. I then reached the same conclusion as the author of tonight's paper, i. e., there is one first principle of curing slides, and that is drainage. If one can get rid of the water he can get rid of the sliding. We drained a great many of the cuts, particularly those which were more or less wet, on the Pennsylvania railroad around the city of Philadelphia, before we undertook to do any sodding or any seeding.

My next experience was in Wisconsin and Michigan, when I was connected with the Chicago and Northwestern Railway as an engineer. On what is now the Ashland Division of the Northwestern

Railroad there were a great many old trestles, built in the early days across swamps of various kinds. They became worn out and it was thought it might be good policy to fill them up instead of undertaking to rebuild and maintain them. It was there I had a great many curious experiences and reached the conclusion that there were no two slides alike. These naturally were more particularly subterranean slides due to overloading swamp mattresses. Near Pelican, in Wisconsin, we filled up a trestle, the foundation of which was understood to be firm. The man who drove the original piles was still employed by the company and told me how hard the driving was, that there was no question but what all we would have to do would be to fill up that trestle work. We filled it up. I remember that afterwards one of the piles stuck out of the ground with its point up outside the right of way. The whole trestle turned over.

Up in the Gogebic Lake region, after filling a swamp for some time and wondering where all the material was going to, one of the engineers went on a little fishing trip, possibly a quarter of a mile away from the line in the woods, where one would hardly know there was such a thing as a lake; when he came back he said the lake was muddy. We found that our filling was sliding over into the lake.

At Eland Junction I saw one of the workmen take a trout from where the roadbed ran, showing the connection between the trestle we were filling and a trout stream which was possibly a couple of hundred feet away.

Those were slides which more particularly referred to the loading up of a swamp mattress by an embankment. Undoubtedly the subterranean surface there, was on a slope that caused the material we were dumping from our work trains to slide off, and we kept on filling, as Mr. Schenck describes, until we got them filled up.

At the north end of the Kaukauna yard, in Wisconsin, on this same division, there was an excavation made in the early days; the material was of a very shaly character, and after being exposed became running muddy clay. In the earlier construction, at this particular point the engineers drove a row of piling, which stuck up about 8 ft. above the ground, and put timber behind the piling, making a bulk-head. At the time I took charge of the division, some of the piling was rotted out. In that particular case we simply repaired the piling as it rotted out and let it go at that, although I always thought we should have done some tile draining.

On a new line that was constructed in Oconto county, Wisconsin, I recall one swamp particularly where Mr. McDougall, of the firm of McDougall Brothers and McDougall & Sims, first got his start in contracting in filling a swamp. Luckily there was enough mountain to fill the swamp, although we had some doubts about it at times. This swamp broke and the fill would slide in every direction.

Later I had some experience with a few slides in the state of Iowa. One of the members of this Society, Mr. Merrick, has very
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accurately and vividly described the method of treating the slides across the Des Moines Valley under the Boone viaduct.*

Near Moingona, Iowa, made famous by Kate Shelly, there was a cut such as I have attempted to describe at Kaukatna, that kept sliding in. We put in large timber boxes about 2 ft. square, the timber being heavy enough to carry the rail, taking the place of ties. We braced these boxes so that the spacing of the rail was no more than it would be on a tie. We carried those boxes away from the slope of the valley, where we were on the side hill, and drained all of the water away from the embankment just as fast as it came to us. We located those boxes an average of 50 ft. apart and had little trouble thereafter with the Moingona Hill cut.

Mr. Schenck's discussion reminded me of one slide that we had out on the Iowa Division. After being made operating officer of the division, I was called one night to a wreck. The fast mail had been wrecked at Ames. Luckily one of the mechanical experts had been on the train and he had been in the baggage car testing the application of the air without the knowledge of the locomotive engineer. He had a speed indicator attached to the train, and just previous to the accident the speed indicator showed 82 miles an hour, as I recall it. The accident occurred, however, long enough after this, that the records showed that the engineer had applied his air and that he had secured the results of the air, and that the accident was not due to fast running, which was our first conclusion. Mr. Schenck and I studied that matter all day long, as we naturally would. The track had settled and it was a little out of line. It occurred to us that it might be the result of the impact of the great speed and we could hardly come to any other belief. I had ridden over this particular piece of track in the morning and had noticed the section men at work, and had gone over the adjoining track in the evening and noticed that the track was all right. The roadmaster came to me with a theory—an old one. We had just built the double track by widening the embankment and I suppose there had not been enough of a bond made between the new embankment and the old one, and the water got in between those two embankments and followed down the slope.

The new embankment had slid off, that was all, and it derailed the train because the track was out of line and out of surface. That particular place was cured by cutting lateral ditches up into the bank and as far under the track as we could. In fact, we put stringers under the track 100 ft. and filled the lateral ditches with stone, thus making a drain. There were other places on the Iowa Division with which we had the same difficulty, and they were all treated in the same way.

As an operating officer on the Chicago, Rock Island & Pacific Railroad, I had an amusing experience with slides, although it was not amusing at the time. Some of our heavy embankments in Mis-

*Journal, W. S. E. Vol. XI, No. 3, June, 1906, p. 332.

souri commenced to settle and get out of line. The question came up of how to treat them. I had transferred a man from the Northwestern Road in Iowa down to Missouri. In Iowa, and under his direction we had experimented by taking old engine flues and driving them right into the embankments. There would be a wooden plug at the end, and then, after driving these flues into the embankment with an iron rod in the flue, we would knock the plug out, and often draw water out of it, sometimes enough so that the track would settle perceptibly. This man had been a general foreman in Iowa and I had taken him down to Missouri and had made a roadmaster of him. I talked to him about the experiments we had made in Iowa and suggested that he try the scheme on one of the high embankments in his new territory.

A few weeks after that I had the pleasure of riding over that particular piece of track with the General Manager, who wanted to know how we were getting along with the slides. I told him I thought we had them fixed, at least I had a report from the Superintendent to that effect. In a few moments we came to one of the high embankments and found that Mr. Roadmaster had deliberately driven the flues right straight down into the embankment. Of course, the General Manager asked me how I expected to pump water out of those embankments. I went inside the car about that time.

For several years, as some of you know, I was engaged in railroad construction and had some experience with slides, ordinary swamp slides or settlements, on the Somerset railroad in Maine, but we treated them generally as we did in Wisconsin and Michigan.

There was one slide on the Erie railroad, on the line between Pennsylvania and New York, which we simply loaded down until it broke and kept putting in material until it came to a settlement.

In North Carolina and Virginia on the Tidewater and Norfolk and Southern Railroads, I had some construction experience with slides in several places, more particularly on the Tidewater, and with quicksand, which, of course, is a different proposition.

On the Great Western Railroad there were several places in the state of Illinois where we had embankments that always shook. They seemed to lie in sink holes, with no method of draining them, and, so far as I know, they are still shaking.

At the tunnel near the Mississippi River we had some slides on the approaches where we simply put in tile draining.

I am giving you these instances to show that I am still an infant in the business, but more particularly on account of my experiences on the Isthmus of Panama.

About four years ago the engineering profession, Congress, the President of the United States, and many others were very much exercised by an article that appeared in the *New Orleans Picayune* to the effect that the Gatun Dam had sunk out of sight. Possibly some of you may recall it. A correspondent of the paper referred to, had been refused a certain request that he made on some of the

officials (either the railroad or the canal, I cannot say which now) and had written up this glaring account, which did not apply to the Gatun Dam at all.

I was on the Isthmus of Panama for two years. During that time I spent a great deal of time on the reconstruction of the Panama Railroad, and the particular slide referred to by the *New Orleans Picayune* which had caused so much excitement was on the relocation of the railroad at least a mile, if not a mile and a half, from the Gatun Dam. In building the railroad we crossed from one point of excavation to another point of excavation, and there was a draw, as we generally term it, that we had to cross, and we knew it was wet. We had a fill about 90 ft. high. Mr. Ralph Budd, now Chief Engineer of the Great Northern Railway, and one of the members of this Society, was in charge of the work as engineer, and after studying the matter we concluded we would make the fill in three separate lifts. We built the ordinary 30 ft. trestle work and filled it and it stood up. Then we drove another set of trestle work and lifted another 30 ft., which we filled, and it stood up. Of course our base was wide enough for a 90 ft. trestle. Then we drove the third set of trestle work and commenced filling. I think it stood all right until we had about 85 ft.—possibly 86 ft.—of dirt in the fill. We all concluded it was a very well-behaved fill. The next morning we changed our minds. It had slipped out of sight and carried all three levels of trestle work with it: there was a hole about 90 ft. deep, if not deeper, and 400 or 500 ft. long, and it was crooked and twisted in every shape imaginable. We studied that slide and that settlement for at least a week. We kept building trestle work, and filling them. We lost them twice. When the fills settled they pushed the material up at the sides, as a settlement will in a swamp or wherever there is a settlement. One day an idea occurred to me that we might go to the outside edge of the settlement, and load it down so that the entire mass would counterbalance. That is the way the bank was built and the railroad is running on it today. You can call it a theory or whatever you choose.

There were other embankments, one something near to a mile in aggregate length, in three or four separate pieces, where the railroad swings around and crosses the sea or river, and they were all treated that way. The fills were made outside of the slope. Afterwards the fills were made inside of the slope and the whole embankment was watched, and if there was any settlement we put a little more on the outside edges and counterbalanced the fill.

There was only one slide of any importance, so far as the canal was concerned, on the Isthmus of Panama, when I went there some five years ago. It was at Cucaracha. That was near the south end of the canal some distance from Pedro Miguel, and has been referred to frequently. I went into the jungle back of the slide and found cracks or fissures 600, 700, or 800 ft. away from the cut. The slide was very gradual in its slope and progress, and they kept taking the material out, from the front in the cut, which is their method of

treating the slides. They concluded that at last they had that slide cured and I think the slide rested for about two years, but I notice in the *Canal Record* that it is on its bad behavior again, and is pushing out into the cut.

Since that time there have been slides all the way along through Culebra Cut. Possibly the second one in magnitude, and the one which I had cause to study, was at Empire. When the French excavated material near the surface they piled a great deal of it very close to the edges of the cut, as they excavated it. The town, Empire, is built on a portion of the filled material that the French excavated and piled up. As the Americans went on down and took away the support from the foot of the slope, this old fill commenced to cave in, and I was compelled to settle for some forty houses that went in with the cut.

An interesting slide on the Isthmus of Panama was described by Mr. Budd in one of the engineering papers. I do not see it mentioned in the author's list, but I am quite sure that the construction of the Miraflores tunnel was described by him.

I know most of you have an idea that the Isthmus of Panama is so flat that there are no tunnels, but we did build a tunnel. The engineering profession is often accused of doing unnecessary things and you may imagine we built a tunnel just to show we could do it; but our location took us through a hogback south of Pedro Miguel and called for a tunnel about 800 ft. in length. About one-half of that tunnel was in hard material and the other half was in soft material. It was a full size 5 ft. gauge, single track tunnel. In the hard material we centered about every 10 or 12 ft.; sometimes we ran more chances than that, and sometimes where the roof did not look good we put the centers in closer. During that particular dry season, or, say, half of the dry season, we got the north end of the tunnel in this hard material concreted with reinforced concrete, in good shape, and the south end of the tunnel open and centered. We used 14 by 14 in. timbers and averaged 4 ft. centers in the south end so there was not much room between supports. Some of the centers were a good deal closer than 4 ft.

I had occasion to return to the States from the Isthmus, and, much to my surprise and disgust, a few weeks after I left I learned that the south end of Miraflores tunnel had closed up so tight that a cat could not get through it.

Alongside of the tunnel, on the east side, running nearly parallel with the center line, possibly with an angle of 15° , was a ravine. The hill itself possibly had an angle with the center line of the tunnel of about 45° , and the slope of the hill itself was very steep—possibly 15° or 20° .

When I returned to the Isthmus I inspected the slide and found that it had completely closed the south end of the tunnel for about 400 ft. We afterwards drove around the outside of that center and the big 14 by 14 timbers that we had in there were twisted all to

pieces. At that particular point I suppose the surface of the ground was 100 to 150 ft. above the tunnel, and yet the effect of the slide down in the tunnel had twisted the timber all to pieces. This slide was not the effect of any lack of drainage (we had good drainage in the tunnel) and it was simply due to the excavation of the ground at the portals making a disturbance on the slope and in the tunnel, opening cracks, which filled with water from the excessive rainfall during the few weeks in question. This water percolated down to a greasy slope and allowed the mass to slip and slide.

The question of how far one might have to go for a foundation for a subterranean wall on the Isthmus of Panama would depend, of course, on the location. When I reached the Isthmus of Panama it was the intention to build the Panama Railroad from Gatun across an arm of the canal about 7,000 ft. long, where they advised me that the soundings were 90 ft. in depth. The Chief Engineer, however, told me that he had no faith in the soundings. I told him I did not care to put a 90 ft. embankment 7,000 ft. long where he had no faith in the soundings. We determined to make another set of soundings and found 90 ft. soundings in some places. There were other places where we broke through what seemed to be a submerged mat and we went down 300 ft. in some places for a foundation. We did not build the railroad across that arm of Gatun Lake. It was diverted eastwardly along the Gatun River and then around crossing the Gatun River, and, in fact, there are seven miles of a diversion line that can be shortened three miles by building a cutoff which will have an easier grade than the line that is now constructed and operated.

Years ago the French built a dock at La Bocha, that is the Pacific entrance of the canal. The records indicate that they went 80 ft. with caissons for foundations. When the American forces commenced to build a connection between the main land and Noas Island, where the quarantine station had been located, by filling trestle work for several miles across the sea, and which filled land connection was also for the purpose of cutting off certain channels that were affecting the main channel of the canal, the caissons supporting the docks began to move and tip over. The filling was at least a quarter of a mile away from the dock, and we had to request the Isthmian Canal Commission to stop their filling, because the dock was going out of line and we did not know where it might go. The Panama Railroad was originally to have been built on the bank of the canal through Culebra Cut. I protested, as I did not think it was wise. A committee of engineers was appointed, and I was outvoted. Two separate decisions were made that the Panama Railroad should remain on the bank of the canal, as it might be useful for repair purposes. Since I left the Isthmus, the Panama Railroad has been built *around* Gold Hill, due to the fact that they have lost confidence in the bank of the canal on account of the slides of some of the harder material which was not affected during the time we were discussing and considering the subject.

It is my belief that all of the trouble at Panama is due to underground movement. I do not think there is a spot along the canal on the Isthmus of Panama where there is any earth moving, that it is not so far below the ground, moving as a mass on the strata beneath, that it would be very hard indeed to say to what depth one might have to go for a foundation.

I have already explained the conditions at Gatun, where we found soundings of hard material 90 ft. deep and the same soundings 300 ft. deep within a distance of 200 or 300 ft.

I would not undertake to tell you how much rain there is on the Isthmian Canal. I saw in tonight's paper a statement that some of the railroads in the Southwest are out of service because there had been 4 in. of rainfall in 24 hours. It does not rain that way very often on the Isthmus of Panama, that is, for any length of time, but while it is raining it is full of business and 4 in. would be a very modest amount for 24 hours rainfall.

At Bohio I saw a slide in the solid ground where large trees were brought down on to the tracks of the Panama Railroad some 500 ft. away from the foot of the slope. There had been no excavation there at all. It was nothing more or less than the rain that had fallen so heavily as to start a hole of some character, and the rain had kept it up until it started a slide which came down onto and covered the tracks of the Panama Railroad.

The Commission is experimenting, as you possibly know, with all the various means that are suggested to lighten the load of the overhang on the slides, and to improve the drainage. I do not think they have made much of a success with any method of treating the slides. If you lighten one load there is another one coming behind the first, and it is coming as a mass and keeps on coming.

It does not make much difference whether you take away the dirt at the top or at the bottom. I think there is no question but what that sliding will continue through the lifetime of any of the gentlemen that are present, and there are some very young men here. I am not a pessimist on the subject, and simply speak from what I saw in the two years I was on the Isthmus. I think the members of the Commission have made up their minds that this is a fact. They have ocean going dredges there and they are maintaining them; they are keeping them in good condition all the time. It might be thought that they could let them run down, but they are keeping them in shape, putting them through the dry docks, and there is no question in my mind but that they have concluded that dredging will have to continue there for many years, for the purpose of taking out material brought in by the slides.

The item, "Solid Strata," in the paper reminded me somewhat of the bad boy on the street that the various civic organizations were trying to correct. One man was trying to scare the boy into being good by fear, and described some sort of a dragon, with a buffalo head, spouting fire and all that sort of thing. The boy after listen-

ing to the awful description, looked at the man and said, "Gwan, there ain't no such animile."

I do not believe there is any such animal as solid strata on the Isthmian Canal. The Bas Obispo cut was taken out of solid rock with channeling machines. You have already heard how they tried to save it with cement guns, but it is crumbling away. The exposure to the air I think has a great deal to do with it.

The only comment I would make as to attempting to stop the slides on the Isthmus of Panama in the method described by the author tonight is that it would be impossible to find any place where sliding may become dangerous that is not already moving. The whole Isthmus near the cut is moving towards it. There may be a place or two where it is not, but I think that this general statement can be taken as true, and I do not think there is any question of the conclusion of some of the engineers, who claim that the only thing to do is to keep on digging the stuff out. If there was any way of draining the slope we might cure the slides but otherwise we cannot. The cost of doing anything in the way of building subterranean walls on the Isthmus of Panama would be prohibitory. However, that is simply a question of opinion. I have described to you some of the experiences I have had with slides; and these experiences convince me that the only thing to do is to keep on filling them or to keep on digging them out.

Ernest McCullough, M. W. S. E.: It was my good fortune to be stationed for some time, a number of years ago, at Cascade, the city of which Mr. Schenck speaks. I had considerable experience in that section with sliding ground.

Mr. Slifer says truly that each slide is a separate proposition to be considered without reference to other slides; except possibly that experience with a slide will be of assistance in dealing with the general problem. The general opinion, gained through experience, in that section was to keep on filling until a condition of equilibrium was established. With such material we must remember that it was put in place as a talus and has been heaped up by one layer after another sliding down over earlier deposits. The engineer makes an embankment by spreading his filling in thin layers, beginning with the widest section, the bottom, and forming the side slope as the work proceeds. It is thus possible to make an almost vertical cut in an old fill. Nature never builds slopes in that way. Nature generally commences at the top of an almost perpendicular bluff, and crumbles the exposed edges off, so the material rolls to the bottom. Consequently when a cut is made at the bottom the whole hill begins to move.

Mr. Rice mentions the hopelessness of endeavoring to stop a movement once started. Men who have money to spend are always willing to take chances on the earth standing, and if movement begins engineers are supposed to stop it. Everyone is agreed that the cost of preventing a slide is less than the cost of controlling a

big one, but even the cost of prevention will be enormous in the case of the Panama Canal and no retaining walls will be put in to stop a slide that has not manifested itself. We all know that with such enormous slides as those at Panama the cost of walls to stop the movement will be prohibitive, so there, as elsewhere, the sensible thing will be to keep the movement under control and watch it carefully until a condition of equilibrium is obtained, or until all the loose material is gone. On a small scale, work such as Mr. Rice recommends can be done.

At Sausalito, California, where I lived for some time, a Mr. Ambjornsen did some interesting work along the water front which may be of interest to those here. Once a bad storm washed away part of the roadway at the foot of a bluff on which some fine residences stood. The naked rock bluff 100 ft. high was exposed, where previously there had been beautiful grounds. Mr. Ambjornsen dug a trench 8 ft. wide and 4 or 5 ft. deep in the rock at the foot of the bluff and laid heavy timbers in it. Using these timbers as a sill he rested others on end on them, running these uprights clear to the top of the bluff. He used the trunks of redwood trees about 18 in. to 20 in. diameter. Cross timbers were used for bracing and then on brackets he placed shelves to form terraces. Then earth was filled in and the gardens restored. It was done in 1893 and will probably last for centuries. I had charge of another piece near by but used concrete instead of wood. The cost was almost as great as the price at which the property was held before the slide.

In Idaho, in building a road about 12 years ago, we hydraulicked our cuts along the river bank by pumping water with pumps placed on flatboats anchored in the river. Unfortunately a break started about a quarter of a mile back and during the winter, which was unusually wet, a long section slid into the river. We cut a deep trench close to the bottom down to the original rock bottom and filled it with rubble concrete. After this had set the loose earth in front was hydraulicked out and the retaining wall held the slope after that. This was on the idea presented by Mr. Rice, but the area was comparatively small, although it looked big to us.

At another point, slides gave us so much trouble that after a trip was made to the Turtle Mountain district the line was relocated. By that time there was enough traffic to justify it. It was a hopeless thing to attempt any other remedy.

John F. Hayford, M. W. S. E.: Mr. Rice's scheme as presented in his paper, seems to me a very interesting and ingenious one, and a scheme which is probably applicable in a good many places. I am interested in the Panama Canal, as most people are, and for eight days I had a chance to see it under very favorable circumstances. I am not an expert in construction nor have I expert knowledge of the Panama Canal so if I state my conclusions positively, it is not because I am certain they are right but because I can state them positively in a shorter time than I can state them cautiously.

It seems to me that Mr. Rice's scheme is not the best plan for
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avoiding trouble with the Panama slides, and that it is clear that the best plan is simply, after the canal is opened, to keep a very keen lookout for the beginning of the slides. That lookout can be kept by soundings in the bottom of the canal, in part by using a wire drag, and also by patrolling the tops of the slopes. Most of the slides show first by a hump in the bottom of the canal and by cracks in the slopes or at the top. Keep that watch and keep the steam shovels ready and also the great dredges. In short, keep close watch so that you can start an even race with a slide, and then race with it, just as they have done throughout the construction of the canal. They have kept up with slides in the past and so they can keep up with them in the future. Probably the canal would not be closed for a day on that plan. If it were closed it would be but for a few days at the most.

That proposition is based upon this kind of an estimate, which has been made. Assume that the slides will continue to perform in the future as they have in the past few years of construction. The capacity of the steam shovels and the dirt trains that can work on the upper side of a slide is known, and the capacity of the dredges that may work at the foot of the slide is known. On the assumption that the slides will perform in the future as they have in the past, the estimate is that probably the canal will not be closed for a day on account of slides, and there certainly would not be any slides that would go fast enough to endanger any vessels in there.

That estimate is on the assumption, that the rate of sliding in the future would not be greater than it has been in the past. Is that a fair assumption? It seems to me that the only reason for thinking they may be faster in the future than in the past is the one stated by the author, that there will be a disintegrating effect of circulating water hereafter that did not occur in the past, which will be an influence tending to make the slides go faster.

But there are several other influences that tend to make them go slower. With lapse of time, of course, slides will tend to slow up of themselves; material will tend to approach a stable condition. There have been very rapid disturbances of normal conditions during the construction of the canal. When you stop those disturbances the movement will continue for a time, but the material will tend to approach a stable condition. The back pressure from the water is a very small amount, as the author has noted by quotations, but it is of the right sign to slow up the slides.

Another thing will be very radically changed when the canal is opened. I suppose it is still true, it was a year ago today, that a sever track railroad ran through the bottom of the cut, besides a number of tracks part way up the side and on the top. If I am right, they had 100 locomotives in the Culebra division, hauling off dirt. That makes a considerable amount of jarring going on in the cut all the time, helping to touch off the slides. Besides, there were several tons of dynamite being touched off in the cut every day and those

little earthquakes ought to help sliding. All that jarring is over with when the water is once in the canal.

The tendency, then, of all these things, it seems to me, is to make the estimate safe, that is, based on the proposition that the slides in the future will be no more rapid than in the past, and the estimate on that basis has been made that the canal would not be closed for a day on account of the slides, if the plan is followed of using the dredges, steam shovels, and inspection as proposed. The dredges can be used there without stopping the traffic. Even the Culebra Cut part of the canal is wide enough for that.

That, in my opinion, is the scheme which is bound to succeed. Of course it is a permanent scheme, because every cubic yard taken out lessens the difficulty for the future.

Consider the author's scheme as applied to this particular case of the Panama Canal. Where will he put his submerged dams? Shall he put them at the toe of the slope where he has shown them in the paper? The first movement observable in these big slides is frequently in the form of a hump in the bottom of the canal. If we are going to stop that it seems that we ought to put a floor over the bottom of the canal rather than a dam at the toe of the slope, and that makes a considerably greater construction apparently than the one he has in mind. But suppose we do put the dam at the toe of the slope, as he suggests. He says that as the flow may be deep there, put the dam in deep enough. Is it possible to put it in deep enough? He says in one part of the paper that the only hindrance to going as deep as you please is the cost; but he also says you cannot work the scheme, you cannot dig the hole, if the material is in motion. It is quite certain, as Mr. Slifer I think, has said, this material is in motion at various places and the motion of the material itself will probably prevent going to any great depth. But besides the difficulty of locating the dams or floors with reference to cross-section, how are you going to locate them with reference to the length along the cut? The cut is seven or nine miles long, according to which of two ways you reckon, and the total length of the dam you would have to build to catch all the slides is from ten to fourteen miles, probably—a very large amount of construction. It is not one locality that is subject to slides, but many localities, so there are miles of the dam to be built, as I understand it, if we are to control the matter in that way.

I have spoken of the difficulty of finding where to build the dams. I take it that the author's idea is that you must build the dam at the critical point. Where the material is just about to move, where the stresses are all just about up to the strength of the material or very near that point, is the place he would build the dam. I submit that such a point is like the trigger of a spring gun. In the author's scheme, it is proposed to fool with the trigger by digging holes 100 ft. into it and shooting the holes with dynamite. I think that will pull the trigger and will make slides.

Another point as to where to put in the dam. I would like to call attention to Plate II. It represents a characteristic case often seen at the Panama Canal. There is drawn on that diagram three locations for the surface of the ground at different times, and you will notice that the material half way down the slope is humped up. The material has behaved like an avalanche coming down the slope by humping up at a point part way down the slope. This seems to me to make it clear if there had been a dam down at the toe of the slope the material would simply have gone over the dam down into the cut. In fact, much of the movement has taken place in this case away above the toe of the slope. A dam would not hold that slide and there are often other cases where it certainly would not.

So it seems to me, as an inexperienced opinion, that the only safe way, and the cheapest way, to handle the trouble from the slides that certainly will occur for several years along the Culebra Cut, is to keep a very keen watch to get an even start in racing with them; to watch for the beginning of the slides and then make it a race between steam shovels, railroad trains, and dredges on the one hand and the slides on the other. The management have won in this race during construction and certainly they could win out hereafter while the canal is in operation.

Mr. Stern: I will call on Professor Grant to tell us what he thinks of this matter from the standpoint of the geologist.

Professor U. S. Grant: One of the important things which the author brought out, is the matter of drainage. This should be attended to carefully. First, all the water possible should be kept from soaking into these soft unconsolidated deposits; in other words, surface drainage should be good. Second, the water which does soak into the ground should be removed as quickly as possible. As Mr. McCullough said, in making excavations we disturb the natural slope and so cause material to descend rapidly, but it should also be borne in mind that in deep excavations we disturb the level of ground water, or the water table. Under ordinary conditions above the water table, the common processes of rock-decay (weathering) hydration, oxidation, and carbonation, or the formation of hydrates, oxides and carbonates—take place. These processes tend to disintegration and in many cases to solution, and the result is that rocks are made weak and less able to stand in steep banks. Excavations lower this level of ground water and so cause the process of weathering to descend deeper and deeper into the ground and with it comes disintegration of the rock and consequently slides. As the water level at Panama is comparatively near the surface, excavations easily lower this level and so slides become more frequent.

The author spoke of a retaining wall and the advisability of keeping the ground water as quiet as possible. Such a wall would probably raise the level of the ground water back of it and so raise the level at which weathering goes on, and the less water moving through the ground the less effect it would have on the material

making the sides of the cut. So both the raising of the water level and the keeping of the ground water from moving much, would tend to prevent softening of the rock and so tend to prevent slides. When the water is turned into the Culebra Cut the water will, as I understand it, be about 50 ft. deep in that cut; is that correct?

Mr. Slifer: The water will be about 40 ft. deep.

Professor Grant: Then the water level on the sides of the cut will be raised 40 ft. and consequently there will be 40 ft. less of rock which is being exposed to weathering; that is, the processes of decay will not extend as deep on the sides of the cut as they do at present, nor will they extend as deep back a considerable distance from the cut. The result will be, then, I may venture to suggest, less trouble with slides after the canal is full of water.

Mr. Slifer: I think there is no question of the general fact, as stated by one of the speakers this evening, that the repose of the material of the Isthmus of Panama inside of the next year will be so materially different from what it has been in the last five years that the slide conditions will alter rapidly. In addition to the engines that are referred to at Culebra, which are housed at Pedro Miguel and which haul the material south to the Pacific entrance, there are also engines at Empire or at Las Cascadas that haul material from the cut to the north. There are steam shovels, and there are dredges. There are tons of dynamite being exploded. These things make one think there is an earthquake going on every once in a while.

After this work is once completed, I think a great deal of the material which will not stay in repose, at its present angle, due to that continual trembling, will possibly take a new angle of repose, and then they will not have so much trouble with the slides on the Isthmus as they are now having.

I think there is no question of the fact that there is machinery enough, with the watching which has already been suggested, to keep the canal open. Culebra Cut is 300 ft. wide. We have no vessels as yet 300 ft. wide, so there will be room enough to keep the cut open and keep the vessels going through.

E. N. Layfield, M. W. S. E.: In common with most engineers who have been engaged in railroad work, I have had more or less trouble with slides, but I have had no particular knowledge of Panama and therefore I do not think I can add much original information. I am strongly impressed, however, with the points brought out by Professors Hayford and Grant and also emphasized by Mr. Slifer, that the conditions which are producing these slides are very materially changing. It seems to me that, to a large extent, this is the answer to the problem.

When these disturbing influences, such as the rumbling of the trains, the blasting, and so forth, are removed and when this ground water line, which seems to me a very important point, as described by Professor Grant, has assumed its new level, I feel that conditions will be largely remedied of themselves.

Of course, having no first-hand information from Panama, I am not prepared to say how bad the conditions are, but from the information we have received from Mr. Slifer and other sources, they must be bad there now. However, as stated, it seems quite probable that the conditions will be materially improved automatically. I have had considerable experience with small slides in railroad cuts, and of course we all know the crude method of setting railroad ties in the ground at the bottom of the slope and a little farther up, and so forth, and a very natural thing is to find some way to anchor those ties or other construction, into the ground, and as Mr. McCullough has described, he did so in the case of a retaining wall. The scheme seems a very inviting one and is entirely logical up to a certain point, but apparently these conditions at the Panama Canal are titanic and not such as can be handled by ordinary methods. It seems to me about the only thing that can be done is to simply let the slopes slide until they come to a condition of repose.

Robert A. Cummings, M. AM. SOC. C. E. (by letter): This timely contribution to the scanty supply of engineering literature on earth pressures, and the references to the great earth and rock slides at Panama and Turtle Mountain, will serve to emphasize the unsatisfactory state of our knowledge of the subject.

Earth slides of a more or less considerable magnitude are continually occurring throughout the United States without being noticed except in cases of disaster. Yet those great pioneers of our modern civilization, the railroads, with their large technical organizations working in silence, have had many experiences that offer a fund of information.

From the time of the clearing of the forest and the first disturbance of the virgin soil to the present time there are earth slides to be encountered along the right of way. Why? Simply because of the arbitrary assumptions in practice. Is it not a fact that the rules for earth slopes are laid down without reference to any particular case? Is it not true that the physical characteristics of earths are rarely uniform? If so, how is the arbitrary practice of $1\frac{1}{2}$ to 1 slope for earth, etc., justified? When it is found that the standard earth slopes will not conform to our assumptions we silently remove the earth slide and forget it. Hence, our opportunity for study and for applying the great dogma of the engineering profession is lost. It is easily asked, "How can the proper slope be determined in advance?" With present knowledge it cannot. But, why should it not? If engineering is applied to science, there seems no logical reason why the physical characteristics of soils cannot be classified and their practical values determined in a scientific manner.

The subject is ripe for the very best thought and study. It appears to be the most fruitful field for original investigation that is now offered. In this connection attention is directed to the influence of moisture and the resistance due to cohesion of the soil on

earth slopes. The absorption of moisture frequently unbalances the earth slope equilibrium by the decrease of internal friction in the soil.

It is also suggested that earth tremors from distant earthquakes or heavy blasting operations frequently lead to upsetting the earth slopes that had previously existed in a state of balanced equilibrium. The influence of these forces is certain, but difficult to estimate. Is it not probable that the Panama earth slides have been influenced by earthquakes in the vicinity?

Regarding the ambitious and ingenious scheme presented by the author, there are many practical difficulties that would have to be encountered in constructing such a retaining wall. Its adoption will necessarily be dependent upon favorable comparison with other methods.

Col. Geo. W. Goethals, Chairman and Chief Engineer Isthmian Canal Commission (by letter): Our present trouble with slides is almost entirely with those which began their movement long since. In these cases I think it is manifestly impossible to stop the motion and we must be content with excavating the material. Our choice is simply whether we shall excavate it from the lower level after it has come into the cut, or from the higher level. When the material is still comparatively firm, it is possible to do this excavation on the higher level even in front of the crack which forms the rear boundary of the slide.

The greater part of the cut has already been finished, and the walls are standing reasonably well, although they have been exposed to full heights during periods running up to two years and for part of their heights during many years. I do not think this portion of the bank will need any further treatment, and in the parts where slides have already begun, I feel that a preventive will not be of any assistance. Were it possible to select a section of the bank with certainty that a slide would occur there if left alone, and then apply Mr. Rice's method, a convincing test might be had. It is, however, impossible to predict where a slide may take place until the motion begins and I shrink from the expense of attempting the application of this method to the many miles of bank where slides may take place, but where there is no indication of them at present.

Donald F. MacDonald, Geologist, Isthmian Canal Commission (by letter): The proposed methods of preventing slides, while they may be very applicable in many cases, could not be advantageously applied to the Culebra Cut slides, for the following reasons:

1. The weak crumbly rock in which the slides occur extends several hundred feet below the bottom of the cut. There would therefore be no chance, except possibly at very great cost, of grouting steel rods into a foundation so that they would hold against heavy earth pressures, such as those which might be expected by one quarter to a million cubic yards of material.

2. The large slides are not the mere slipping of relatively loose

material off a relatively solid base slope, but include a slow movement or deformation of the base slope itself, to depths well below the bottom of the excavation. This often involves a "swelling" upward of the rock floor of the cut. Such movements would greatly complicate and add to the cost of retaining walls.

3. Slides containing more than a million cubic yards have occurred in the past. A system of retaining walls that would not yield to the earth pressure of such a mass would be a most costly affair, especially as there is no solid rock to make a strong natural foundation for such a system.

4. There have been large slides in Culebra Cut in the past and there are some more yet to come, but these really do not present a problem. Just as soon as the slopes of the cut are made flat enough there will be no more slides. This work of flattening the slopes is now well under way.

5. The chief reason why there were and are slides in the Culebra Cut is because the slopes of it were made too steep for the weak and crumbly character of the rocks involved. There are many relatively steep sided valleys in the zone. These have been excavated by streams in the same kind of material through which the canal is made. When the slopes of the cut shall approach the natural slopes of these stream valleys, the sliding period will certainly be closed.

6. The cost of terracing back the upper slopes and making the walls of the excavation slide and deformation proof will be much less, and will certainly be more effective, than any system of retaining wall could possibly be under the geological conditions that govern the case.

James E. Howard (U. S. Bureau of Standards): The paper is a very interesting one and I am glad of the opportunity to participate in its discussion. It treats of such a difficult engineering problem that I hardly feel competent to say much on the subject. However, as I have viewed the situation it seems that a retaining buttress of any kind would need to cover the entire face of the cut, now referring to conditions at the Isthmus. Just as soon as the vertical face is disturbed then the heavy tropical rains begin erosion, and I fear also that in time the depth of cut which would endure would be very limited in depth, and nothing like that which has stood for a season or two. In other words, it leads to a retaining wall to cover the full depth of cut or go to the other extreme of a very flat slope, and get vegetation to cover it as soon as possible.

Some of the essential features involved in the subject of rock slides and earth pressures pertain to the strength of materials. The stability of rock masses brings into consideration the behavior of materials under different pressures, at times of enormous magnitude, both in a confined state and when lateral support is relieved or absent. Experimental data upon the behavior of materials when subjected to high pressures are comparatively meagre. Some examples will be referred to which have come within the experience of

the writer and which seem to have a bearing upon the subject under discussion.

First, in respect to the effect of compressive stresses upon confined materials. Certain materials, of moderately high compressive resistance against loads applied in one direction, have displayed an ability to sustain, when in a confined state, stresses up to the limit of experimental inquiry and have given no indication of approaching the limit of rupture or impairment of structural integrity.

For example, a sandstone having a normal crushing strength of about 10,000 lb. per sq. in. was exposed to a stress of 35,000 lb. per sq. in., when in a confined state, resulting in no apparent injury. Again, a cylinder of neat Portland cement was exposed to a compressive stress of 100,000 lb. per sq. in., which still retained its integrity unimpaired. In each of these cases the materials were placed in an hydraulic cylinder and loaded from all sides. Thin sheet metal encased the stone and the cement, preventing access of water to them. Mild steels have similarly been subjected to cubic compression with loads some three times their elastic limits without causing any change in their physical properties.

It seems, therefore, to be a matter of strain and not stress which tends to destroy the materials of construction. There is no reason for supposing that deeply buried rock is not structurally sound. But what the physical properties are under such conditions, and how they compare with those with which we are familiar, is conjectural.

Along this line of thought it may be remarked that mild steels have been found to flow continuously under compression loads of some 85,000 lb. per sq. in., pressure being applied in one direction, the material being unsupported laterally. In contradistinction to this behavior of a fairly rigid material, it has been found that a mixture of wax and tallow would not flow through a small orifice, under a difference in pressure of 60,000 lb. per sq. in. In the latter example, the pressure in one cylinder was 100,000 lb. per sq. in., opening into another of less than 40,000 lb. per sq. in. pressure, the connecting orifice having a diameter of 3-16 in.

A result of this kind leads to considerable reflection upon the probable state of rigidity of materials under great pressures at different temperatures.

Ordinary cases of rock slides, however, do not introduce questions pertaining to these very high pressures. The behavior of materials under usual tests represent conditions more general, more closely associated with those present in slides. But our experimental data show that in dealing with rock masses we have material quite variable in its character.

Experiments upon the compressive elastic properties of building stone have shown the ordinary range in values of the moduli of elasticity. Such values correspond well with required values to harmonize with the observed rate of travel of earth tremors in cases of earthquakes. When, however, there is a wide variation in stress,

the behavior of building stone does not always maintain a constant relation between stress and strain.

The ratio of lateral expansion to direct compression, which in the case of steel appears to have a fairly definite value, in the case of stone shows wide variations.

Stones swell in water. They appear also to acquire a permanent increase in volume when moderately heated. A sandstone gradually swelled upon repeated immersion in hot water. After a few repetitions it was so weakened that it fell apart.

Differences in the physical properties may be conceived to exert an influence in promoting rock movements when conditions under which they have been resting are disturbed. Their influence might be felt when rock movements which terminate in slides are first inaugurated. Great interest attaches to conditions which immediately precede slides.

Earth or rock slides at Culebra and vicinity take place in consequence of loss in lateral support of the sides of the cut. They are similar, but on a colossal scale of magnitude, to slides which occur at places here in the States. During the dry season the ground shrinks and opens small fissures, incipient conditions for starting slides. Where clayey soils are found, the lubricating effect of water would be felt upon the return of the next rainy season. The depth of cut which would maintain a nearly vertical face for a term of years could hardly be estimated from the experience of one or two seasons. It seems that a very flat slope will eventually be reached where the material of the cut is of such a character that it exfoliates in the presence of moisture. Tropical conditions are favorable for the immediate growth of a protective covering for the portion of the cut above the water level of the canal.

To the writer it appears that a method of protection to the sides of the cut would need to be carried very nearly to the original surface of the ground to be permanently effective if faces approaching the vertical are retained.

CLOSURE.

Mr. Rice: There seems to be a general condemnation of my scheme by those who have spoken, at least as applied to the Panama Canal, although some engineers with whom I have talked about the scheme, among them some who had been to Panama, were sufficiently encouraging to lead me to prepare the paper under discussion.

I think that some of the speakers, particularly the railroad engineers, have not clearly differentiated—perhaps my own paper does not so clearly differentiate—between slides of unstratified earth material and rock slides.

Mr. Slifer has recited some interesting experiences with railroad fills at Panama and elsewhere. Certainly, that was a remarkable case where an 85-ft. fill sank, leaving a hole 90 ft. deep and 400 or 500 ft. long. It suggests an interesting way of making a canal

if all the Panama formation is as soft as implied. However, it is not clear to me in the remedy employed of parallel fills on either side, if the swamp area was extensive as one would infer, why the outer fills would not slump away since the ground would be unbalanced on one side of each. Perhaps the explanation may be that these outer fills were lighter or else the whole of the soft ground was covered.

While the notes of experiences with fills on soft ground is valuable engineering to record, it does not appear to me to have any bearing on the problem presented for consideration which has to do with unstable natural formations more or less stratified, and either exposed naturally in steep banks or slopes or artificially cut so as to be in danger of sliding.

I do not think the scheme I have proposed of an underground dam would be at all feasible in dealing with earth such as soil or clay, because I do not think you could cement it, although it might be possible with gravel or coarse sand. It is more particularly sedimentary strata like sandstone or creviced limestone, or other fractured or porous rock, which I had in mind. I am not now referring to the plan of a surface retaining wall for a dirt slope, when anchorage can be obtained in solid rock; that plan I think has a wide application.

As I stated, I have not been to Panama and my information about the geologic formation is chiefly derived from the geologist's report. This certainly indicates that there are considerable areas through which the Culebra Cut passes which are sedimentary, viz., sandstone, limestone and water deposited volcanic debris, even some small beds of lignite, and it was in that kind of strata that I had in mind the possibility of application. As to the location where the trial might be made, I did not attempt to point it out. It would be, of course, simply absurd for me to do so not knowing the special conditions. I presented a generalized scheme, only suggesting that in its application the ground or slopes be subdivided as far as that could be practicable.

Regarding the presence of rock which Mr. Slifer's remarks indicate does not exist above a level of 90 to 300 ft. below the surface, while this is doubtless true at either end of the Culebra area, I have considered only the formation found in the Culebra Cut. It is quite evident, I think, from some of the cross sections and pictures that have been shown in the Panama reports, that there must be considerable sedimentary strata there. It is shown in Fig. 7, where big rock chunks are crushing a large steam shovel.

After a slide is once in motion, even strong rock is ground up in small pieces and does not appear the same as before the slide occurred. Sometimes in coal mining we have a material underlying a coal bed that when first opened out, before we have made a considerable excavation, will be very hard; and, when struck with a pick, sparks may fly. But when working on the long wall system,

after the weight is brought on the edge of the coal, the underlying band is crushed and then it acts like fire clay.

One of the gentlemen spoke of my being connected with the Government, in such a way as to cause me to infer that he thought that would lead me to disregard cost. In the work of the Bureau of Mines, at least, costs have to be as closely considered as I found was necessary when I was connected with mine corporations up to a few years ago. In good mining engineering practice it is necessary to consider long in advance and take measures to prevent, at an increased cost, the effect of moving strata, in both the mine workings and on the surface.

Apart from the general application elsewhere, what I had in mind for the Panama situation was that there might be a subdivision of the slopes of the Culebra Cut where the ground was suited, putting several short underground dams, possibly in echelon. I did not contemplate that the whole 8 miles of cut would have to be treated but only here and there where the conditions appeared threatening.

In reply to Professor Hayford's remarks about the continuous jarring of the ground in Culebra Cut by firing large charges of explosive, I fully agree that this probably increases the tendency to start slides, but I think he greatly overestimates the effects of drilling and use of light charges of dynamite deep in the solid formation if there be such. The firing of a few sticks of dynamite would accomplish the purpose of enlargement at the bottom of each hole and is not to be compared with the simultaneous discharge of hundreds of pounds of dynamite in holes close together as now daily practiced.

Of course, we all expect that the canal commission will fight the matter to a finish and I did not mean to imply that I thought the canal was in any sense impracticable or could not be kept open except at intervals. But there is a possibility that slides will give an immense amount of trouble if the bottom rises as quickly as described in the report of a division engineer, who stated that when standing in the canal the bottom where he stood, rose right up so that he had the impression that the neighboring steam shovels were sinking. It shows how rapidly at times the bottom may come up, and no amount of sounding would anticipate it in time to prevent trouble occasionally. If the bottom happened to rise as described under a vessel it might give it quite a lift.

As to the matter of erosion, as Professor Grant has said, the erosion is likely to be considerable. Limestone is soluble. We are dealing with fresh water, namely rain-water. Pure water takes up salts very readily, and it seems to me that unless there is some preventive means there is liable to be disintegration of limestone along the bank. When a great ship passes, there is bound to be an elevation of the surface of the water and following that a depression. This will cause a scouring and dissolving action which I thought might be serious. However, if the water from higher up the slopes

does not keep the channels through the rocks open, in time they may silt up.

While I have perhaps aimed high in taking the Panama Canal as an opportunity for application, it does seem to me that in other places where there have been deep cuts in weak strata, and in which cementation can be carried on, there the process may be of advantage.

ADDENDA.

Mr. Rice: Since the meeting when the paper was presented several matters have been brought to my attention, first, regarding cementation of natural ground. In the *Engineering News* of April 3, 1913, p. 647, there is an article by D. W. Cole entitled, "Making a Cut-off Wall by Grouting Fissured Rock, Lehontan Dam," which is part of the Truckee-Carson project of the U. S. Reclamation Service. It describes a successful grouting of fissured rock under a pressure of 100 lb. per sq. in.

Also in the *Engineering News* of May 8, 1913, H. H. Cartwright has described some experiments in grouting gravel and sand deposits by an injection process. While Mr. Cartwright's conclusions are favorable to the process in spite of an irregularity of cementation, I was impressed that the results obtained in the experiments would have been better if the cementation had proceeded in successive stages from the top downward, as described in my paper. By so doing a cemented cover would first have been formed using very low pressure, which would have enabled higher pressures to be used below to obtain wider penetration.

LANDSLIDES.

Elm (Switzerland) Landslide. The description of the great Elm landslide in Switzerland caused, like the larger Frank slide, in part at least, by excavating, is quoted in U. S. Geological Survey, Professional Paper No. 67 (p. 42). As it seems desirable to bring information together while discussing slides, an outline is here given: The landslide that destroyed the village of Elm in September, 1881, was brought about largely by the hand of man. A bed of slate dipping into a hill, overlooking the town of Elm, had been worked as a quarry for many years and no means taken to support the roof or hanging wall. The latter finally broke (across the bedding planes) after a wet season, demolished the village and killed many persons. A witness states that a mass broke away from the Plattenberg kopf, crashed over the quarry, and shot across the stream, dashing the water in the air. No one was killed by this. A second portion from the east side broke away 17 minutes later, which united below the peak with the first, killed a score of persons and overwhelmed four houses. Four minutes after, the peak itself pitched forward like an avalanche. A cloud of dust and a great wind was flung before it and "the wind swept the valley and overthrew the houses." In all, 115 lives were lost. Ten million cubic meters of rock fell down an average depth of 450 meters (1,500 ft.), shot across the valley

September, 1913.

and up the other slope to a height of 100 meters (330 ft.), covering the valley to a depth of 30 to 65 ft. "The stuff flowed like water."

Goldau (Switzerland) Landslide. Another famous landslide, the Goldau, descended from the summit of the Rossberg Mt. in 1806 burying four villages and 457 persons. Enormous masses of conglomerate and sandstone became loosened along lines of stratification and slipped bodily from the face of the Rossberg peak to the valley. The inclination of the beds was about 12° while that of the slope on which they slipped was about 20° .

Slides Resulting from Mining. In the Lake Superior iron mining district the question of slides from the banks of deep pits is becoming increasingly important. Not only to the mine operators but also to the surface improvements. In the Michigan district, mining is done by the different forms of the caving system. In many instances when the ore body is large or the excavation has begun at the surface and later change has been made to underground excavation, in either case, great lenticular pits result, the bottom of which is more or less covered by waste rock falling from the slate or quartzite walls and borne on a mat of crushed timber over the active workings. As the workings get deeper, the loose rock at the bottom lowers, thus constantly increasing the height of the unsupported side walls. In some cases the height is over 300 ft.; evidently this is too steep for the average rock to stand unless horizontally bedded. In most instances in these districts the bedding is on edge or steeply inclined, so that the beds buckle out at the bottom and a slide results.

At the Chapin mine, Crystal Falls, Mich., the tracks of two railroads and a county road are carried on a great fill over the pit caused by mining. This fill is having to be constantly built up as the bottom goes down, the sides constantly widening by slides.

The writer is not prepared to offer a remedy for these mine cave problems as the depths are constantly increasing, hence there is no footing for a retaining wall, but he desires to bring it to the attention of engineers as an increasingly serious problem and one where rock slides can be studied with great advantage. The writer has endeavored to express some phases of the problem in the following notes.

NOTES ON LANDSLIDES AND SLIDES FROM MINING EXCAVATIONS.

Gravity is, of course, the fundamental cause of rock or landslides. The immediate causes are changes in the equilibrium of forces holding stationary an unstable mass due to either natural erosion or artificial excavations affecting the strength of (a) the buttress holding back the mass or (b) changing the frictional resistance to sliding of the mass. The following are the important factors to be considered in studying this subject:

Angle of Repose. By this is meant the surface slope measured from the horizontal at which loose material will stand on a hori-

zontal base, without sliding. This angle for considerable depths of drained loose material does not have wide limits, 30° to 35° .

Angle of Plane of Sliding from Position of Rest. By this is meant the plane on which a slide will start, the angle of slope being measured from the horizontal. This has a wide range, depending:

(1) On weight of mass per unit of horizontal area above plane.

(2) Whether the plane of slide is smooth like a fault plane, and is lubricated by water or clay.

(3) Character of floor below plane, whether it will "flow" under pressure, like a saturated clay. In this case the angle is difficult to define. If the underclay squeezes out, a mass may be set in motion on a very flat slope, perhaps 10° as indicated by some of the Culebra slides of the Panama Canal.

Angle of Sliding When the Mass Is in Motion. This may be very flat (measured from the horizon) as, for example, in the water saturated ground at Panama, some landslides are moving slowly on an average slope of 1 vertical in 10 horizontal, or a little less than 6° .

Angle of Pull; or Draw in Mining. There is considerable ambiguity as to what this term means. By some is meant the angle between the vertical and an inclined plane bounding the area affected by the subsidence, beyond the vertical. It would appear simpler to use the angle from the horizontal, as in considering slides.

The "draw" or "pull" from subsidence in mining is so called when the influence of subsidence is manifested beyond a vertical plane along the edge of the underground excavation that has fallen, or subsided in the goaf. It is made of two component forces; one the tendency to slide through gravity, and the other of tension due to the pivoting of the roof mass on the edge of the solid strata being mined; the inverted wedge shape mass rotating toward the excavation on the edge of the wedge. The tensile strength of the rock mass as a whole is therefore an important factor; another large factor is whether there are faults or fissures traversing the mass parallel with the axis of rotation. When the rocks interlock, as was the case on the crest of Turtle Mountain, the "draw" or tensile pull was manifested considerably back from the face, 100 to 200 ft. from the plane of break.

On the other hand, when the rocks are structurally weak, like shales, the pull that can be transmitted is weaker, and it is then more a question of the sliding of a wedge-shaped mass.

In open pit workings there are stresses set up by gravity in two ways: first, through a crush at the base, resulting in a sliding tendency, and second, a wedging effect of masses behind the face; this is particularly manifested when the strata are on edge or overhanging. It is difficult in practice to determine what are the respective parts borne by each force. The measurement of a large number of angles of artificial excavations over long periods, is desirable.



Plate I.

TURTLE MOUNTAIN AND VICINITY ALBERTA (SHOWING DANGER AREA)

(From Memoir No. 27 Canada Department of Mines.)

Light shaded area is that from which 1903 slide originated; dark shaded area represents that thought to be threatening (1911)—areas respectively affected and threatened are embraced by dotted lines.

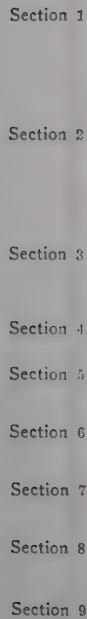


Plate I.

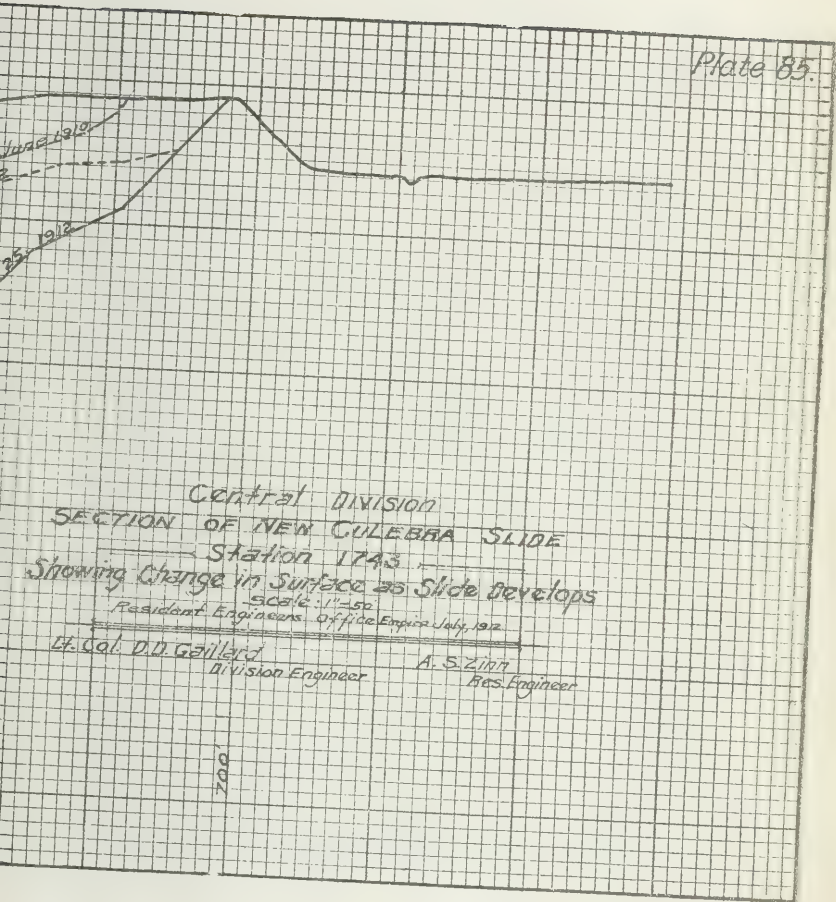
TURTLE MOUNTAIN AND VICINITY

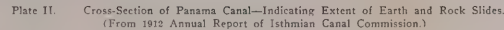
ALBERTA

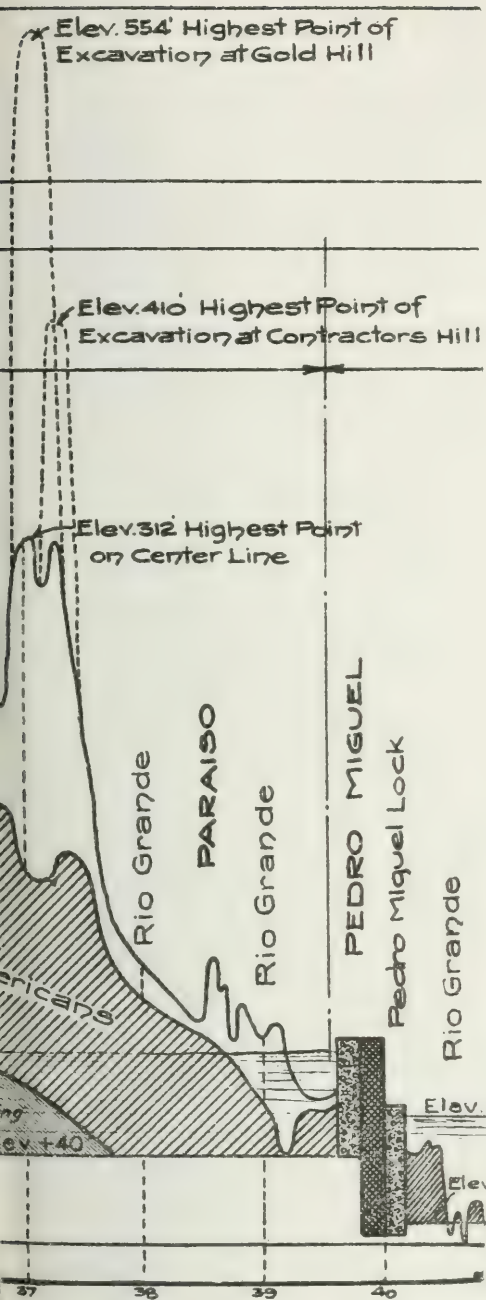
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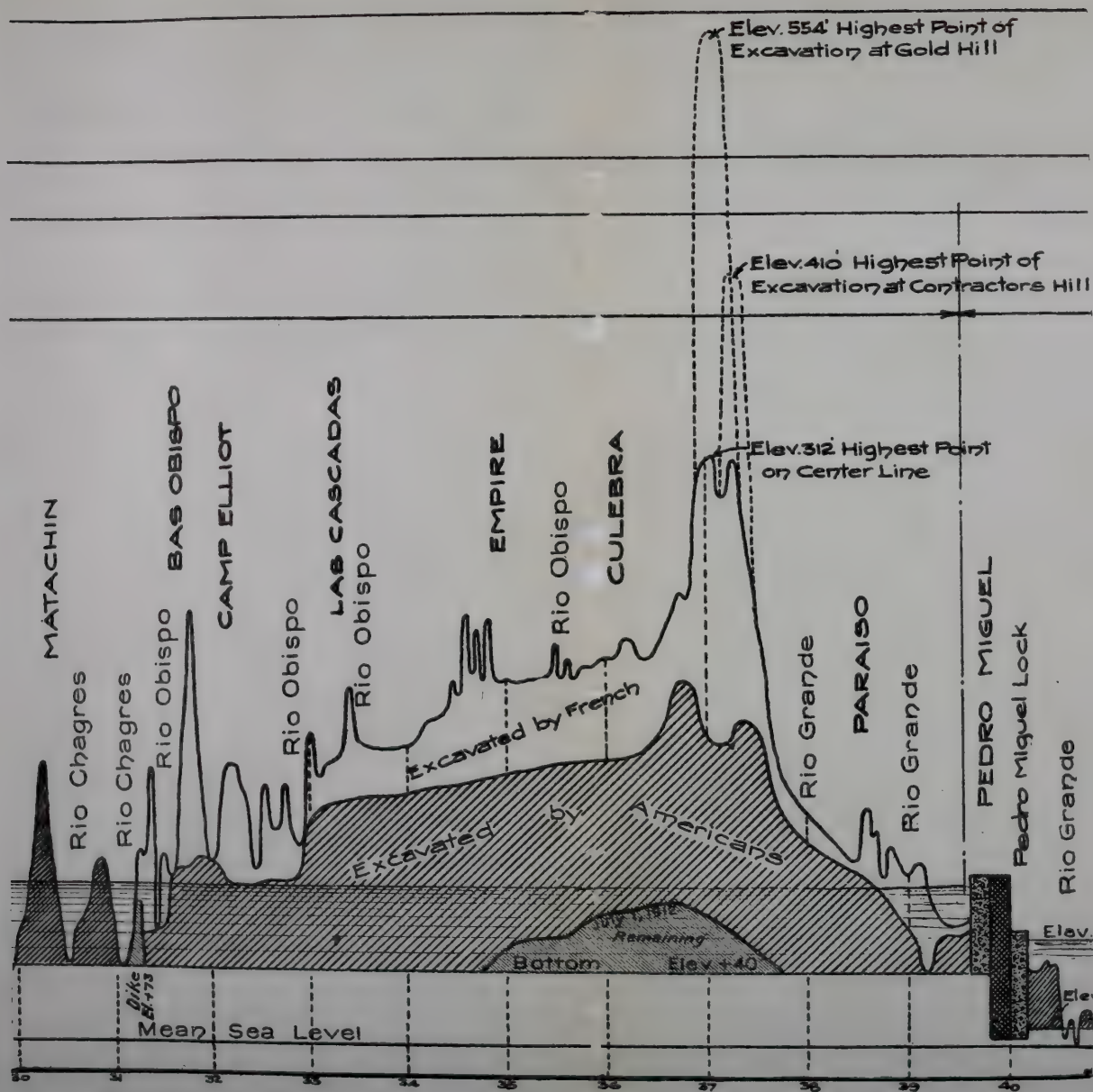
Plate 85.







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IMPROVED MANAGEMENT OF WATERWORKS

PAUL HANSEN.*

Presented March 3, 1913.

OBJECT OF PAPER.

The object of this paper is to advocate the employment, on an annual basis, of consulting experts in connection with the operation of small waterworks installations for the purpose of improving the service, the equipment, and the economy of operation. This is by no means a new practice, but it is exceedingly rare, whereas it should be virtually universal.

The same method may be used for improving the operation of other public utilities such as electric lighting plants, sewage treatment plants, drainage districts, etc. The writer's experience, however, has been principally with waterworks; moreover, the limits of a brief paper will not permit of a broader discussion, and therefore his remarks will be confined to waterworks.

GENERAL METHODS USED BY EXPERTS IN SUPERVISING WATERWORKS.

The means by which the expert's services may be rendered are by occasional visits, say monthly or quarterly, by the training of the men locally employed, by the periodic examination of records and accounts maintained in accordance with instructions furnished by the expert, and finally, by reports with recommendations, submitted at regular intervals. Not more than a few days per month would be occupied by the work involved, and the service may be rendered at what, comparatively speaking, is a nominal fee. For supervising waterworks in a small community \$600 should yield a fair compensation. Perhaps a more satisfactory method would be to base the fee upon the gross receipts, making it a suitable percentage thereof.

NEED FOR EXPERT SUPERVISION.

It is hardly necessary to point out that there is a real need for improved management of waterworks, for the reason that most engineers who have had anything at all to do with waterworks are aware of the very general slipshod methods employed. During the past eight years the writer has had occasion to visit or receive reports upon about 200 small waterworks in the states of Ohio, Illinois and Kentucky, and not an instance is recalled of a small waterworks installation (that is to say, for a town having a population of about 25,000 or less), where thoroughly effective methods of management were being employed. This does not infer that all these waterworks installations were not giving good service. As a matter of fact, some were giving good service, but generally at unnecessarily large expense, and without adequate records and accounts to show where economies might be instituted. The great majority, however, were giving very inferior service and showed every outward evidence of carelessness and neglect in management.

*Engineer, Illinois State Water Survey.

POSSIBLE OBJECTIONS TO EXPERT SUPERVISION.

The method of improving the management herein discussed is not advocated for the purpose of increasing the business of consulting engineers, but because it seems to the writer the only practicable method whereby the desired results can at present be accomplished. In large waterworks, of course, it is perfectly feasible to engage the entire time of an expert and designate him as general manager. In small waterworks, however, it is not possible to afford the continuous services of an expert. The men ordinarily employed, while they may be intelligent and conscientious, have not had the opportunities of securing the necessary training and experience to render most effective service. But such men, backed by an expert, are as a rule capable of securing highly efficient results. More generally it is found that the waterworks has become a political football and is relegated to the mercies of very incompetent men. In such cases the consulting expert has a very difficult problem, but by tact and by appealing to the more enlightened sentiment of the community he may accomplish a great deal and because of the very fact that things are in a run-down condition the results of his efforts will be all the more striking.

There may exist the feeling among some, that the supervision of waterworks should be entrusted to local engineers in general civil engineering practice. This would, as a matter of fact, be an injustice to such engineers for the reason that their numerous other duties and employments rarely permit them to acquire the necessary expertness in the restricted field of waterworks. It would appear, therefore, that no conflict of interest exists between the consulting expert and the local engineer. On the contrary, the local engineer should be the first to recognize the necessity of the services of an expert in waterworks operation.

Some persons lean to the belief that supervision over public waterworks should be maintained by some central state authority, and such supervision is certainly desirable, in so far as the sanitary quality of water supplies is concerned. But to enter into the economic phases of waterworks operation to the extent of giving the close supervision herein contemplated, would be altogether impracticable. It would involve the maintenance of an expensive and cumbersome state bureau engaged in performing functions which are primarily of local concern and, moreover, the mere fact that the services of such a bureau would be foisted on the local community would cause the local authorities to be generally antagonistic toward the bureau's requirements. It is not practicable for any central body to go further in this matter than the State Water Survey proposes to go, namely, to do just enough to demonstrate the value of expert services in waterworks operation and leave the rest to municipal and private enterprise.

September, 1913.

RESULTS OBTAINABLE THROUGH EXPERT SUPERVISION.

Specifically, the results obtainable through expert supervision of a waterworks are:

1. Better service.
2. Reduction of cost of operation, which, of course, means increased earnings.
3. Anticipation of future requirements.
4. Improved design.
5. A professional and personal advantage to consulting engineers.

Better service means furnishing, throughout the community, an ample quantity of pure and clear water for domestic and industrial purposes, and providing a liberal safeguard against disastrous fires.

Decreased cost of operation means a supervision of all the details of operation in such manner that effective service will be rendered at minimum expense.

Anticipation of future requirements means that all necessary increases in the supply and equipment will be foreseen, so that they may be provided before the community is reminded of its needs by destructive fires, inadequate equipment, or disastrous epidemics due to the pollution of the water.

Improved design will result from a better knowledge of operating conditions than is ordinarily obtainable under present practice by those entrusted with the preparation of plans and specifications. The structural features can generally be readily taken care of, but a common fault is a failure to provide for contingencies encountered in operation. Under the present regime the consulting engineer's connection ceases at about the time that operation begins, and if he has any curiosity to learn if his designs are working out successfully he must satisfy his curiosity at his own expense.

A personal advantage accrues to the consulting engineer from supervision over the operation by giving him continuous and regular employment, thus enabling him to maintain his organization intact. Further, it benefits him professionally by enabling him to concentrate his practice within a limited field, and thus he has the opportunity of increasing his detailed knowledge along his chosen line; in short, he renders himself more expert. There are many men in consulting practice today who attempt to cover such a broad field that it may be frankly said they are not thoroughly competent in any one line.

MODUS OPERANDI OF EXPERT SUPERVISION.

For the purpose of illustration and not with any intention of giving a treatise on how to supervise waterworks operations, a brief description will be given of the manner in which expert supervision should work out. Three factors form the basis upon which this work is conducted:

1. Operation Records, relating to the physical facts connected with waterworks operation.
2. Financial Accounts, relating, of course, to the finances.
3. Technical Skill, which is required in obtaining and interpreting the operation records and financial accounts in such a way that all of the needs of the waterworks plant are fully revealed.

It will be of advantage to inquire a little more fully into these three items and consider them separately.

1. OPERATION RECORDS.

Records may be subdivided into several groups as follows:

- (a) Records relating to source of supply.
- (b) Records relating to purification works.
- (c) Records relating to pumping station.
- (d) Records relating to distribution system.

(a) *Records Relating to Source of Supply.* Records relating to the source of supply comprise measurements of the quantity of water available, sources of possible pollution and analyses of the water.

The measurement of the quantity of water available may be made in a variety of ways, some simple, some elaborate, depending upon the character of the source of supply. At any rate, such records are exceedingly valuable in forecasting the adequacy of the source of supply for future requirements. In the southern part of Illinois are two communities each of which obtain their water supply from an impounding reservoir. During the past summer both of these reservoirs went practically dry and remained so for some months. In one case no emergency supply could be secured, the community suffered for want of water for ordinary domestic purposes and was left helpless against a conflagration.

In the case of surface-water supplies, the records relating to the condition of the watershed, particularly if the water is used in an unpurified condition, are exceedingly important. Inspections of the watershed, when intelligently made, are much more reliable than analyses in showing dangers to health. It is merely necessary to mention the Plymouth, Pennsylvania, epidemic of typhoid fever in 1885 to demonstrate the futility of analyses in detecting intermittent pollution, such as was responsible for that disastrous outbreak.

Analyses, however, should not be ignored, especially when it is possible to secure a long series of analyses, as they then become a measure of the pollution and give a record of the physical and mineral characteristics of the water. Where purification of the water is employed, such analyses are well-nigh indispensable, as will be discussed later.

It is much easier to give examples of the evil results of failure to maintain proper records regarding the source of supply than to give examples of water famines and other disasters that have been averted by the maintenance of such records. The latter instances

are ordinarily not recorded and the danger is never realized by the general public.

(b) *Records Relating to Purification Works.* A volume might be written upon this subject alone. Experiences with small filter plants are most disheartening. Practically all of the small filter plants in Illinois, numbering half a dozen or more, are being ineffectively operated. The same is true in Ohio and Kentucky, and, no doubt, in other states. Some of the difficulty is due to bad design. Very small filter plants are apt to embody bad design, whereas the conditions under which they are operated are such that they should embody the very best design.

Expert supervision over mechanical filter plants (those most generally used in the middle west) does not necessarily result in reduced cost because of the prevalent reprehensible custom of omitting the use of coagulant when the raw water is moderately clear, but within the limits of efficient purification the cost can undoubtedly be reduced. The average small purification works is placed in charge of a pumpman or fireman, having many other duties to attend to, and it is but natural that this, combined with his lack of knowledge of water purification, results in almost total neglect. In many instances such men, through ignorance of the danger of impure water to public health, have no hesitancy in by-passing the raw water into the mains when it becomes convenient to do so.

Records necessary for maintaining proper supervision over mechanical filter plants include analyses of the raw and filtered water, the quantity of water treated, quantity of chemicals used, the frequency of washing the filters, the quantity of wash water used, and numerous other details. For obtaining analytical data there should be established, in connection with every filter plant, however small, a modestly-equipped laboratory. It is an easy matter to train any ordinary waterworks employe of normal intelligence how to make simple analytical determinations which will not only furnish the desired records, but will guide the filter attendant in his daily operation of the plant. If the expert has laboratories at his command, additional analytical control may be maintained on a somewhat more elaborate scale.

(c) *Records Relating to Pumping Station.* A small waterworks pumping station for which complete records are maintained, is a great rarity. Often it is impossible to get even an approximation of the quantity of water pumped, and generally the only records are from pump revolution counters without any allowance for slippage. It is a comparatively simple matter to weigh the coal and ash, to maintain pumping records both from revolution counters on the pumps and from a meter placed upon the main discharge from the station, and records of the discharge pressure, suction lift, quantity of boiler water used, etc. With such items as these it is possible to always know the condition of the pumps, figure accurately the station duty, and otherwise reveal opportunities for improvement

and cutting down the demands on the coal pile. The expert can also arrange, where conditions warrant, for purchasing fuel and possibly other supplies on an analytical basis.

(d) *Records Relating to Distribution System.* Most deplorable of all are the records ordinarily maintained in connection with the distribution system. The location of mains, valves, and service connections is generally stored in the memory of ex-waterworks employes and local plumbers who regard these facts more or less as stock in trade, and would consider it business suicide to record them. In many towns there is no vestige of a map of the distribution system to be found, and where such maps do exist it is only occasionally that they show mains laid since the original waterworks installation. It is not strange, therefore, that extensions to the distribution system are generally unwisely made, that fire pressure is often lowest where most needed, and that there are many undetected leaks and thefts of water. In the hands of an expert all of these difficulties may be easily overcome simply by the maintenance of complete maps and plans, by periodic inspections and by occasional tests for pressure, leakage, and waste

2. FINANCIAL ACCOUNTS.

Waterworks accounting, especially in municipally-owned establishments, is usually in a chaotic state. About all that is ordinarily recorded are the gross receipts and gross expenditures roughly itemized. Capital accounts are almost unheard of, and it is often impossible to get even approximately the cost of the plant. In many municipal plants large donations from public funds are calmly included as earnings. Such items as depreciation, allowances for taxes, interest on investment, sinking fund, rent, etc., are altogether ignored. If the gross receipts, no matter from what source, exceed the gross expenditures, no matter for what purpose, a profit is proudly proclaimed. In some instances, on the other hand, large numbers of free service connections make a waterworks appear as a losing proposition, whereas suitable compensation for such services would place the plant upon a sound financial basis.

Correctly-maintained accounts should display fully itemized capital accounts, maintenance accounts, repair accounts, replacement accounts, sinking fund accounts, depreciation accounts, interest accounts, and, in fact, every item that enters into waterworks construction, operation, and maintenance should be carefully recorded in its proper place. In addition, there should be maintained accounts showing unit costs for operation and construction. These latter are very valuable in making comparisons with other plants and with the same plant in other years. Accurately-maintained accounts are particularly serviceable in the adjustment of water rates. The establishment of water rates is, at the present time, on a most unscientific basis and it is common practice for small communities to adopt, parrot fashion, the rates established in some other com-

munity, regardless of the manner in which the water is obtained and the cost of delivering it to consumers.

3. TECHNICAL SKILL.

But little can be said with respect to technical skill. It is primarily a matter of natural aptitude and experience, and it is needless to say that no one should presume to enter this field of consulting practice unless his natural aptitude and experience have rendered him fitted therefor. Aside from the maintenance of records and financial accounts it is necessary for the consulting expert to thoroughly instruct the men locally employed in their respective duties and this necessitates, of course, skill and a thorough knowledge of such duties on the part of the expert. The analytical mind of the expert also enables him to discover opportunities for modifying methods of operation which the more or less untrained man would fail to see.

SUMMARY.

To summarize: The employment of consulting experts to supervise the operation of public water supplies and other public utilities in the small communities, constitutes a simple and the only practicable method whereby the operation of such utilities may be rendered efficient, whereby the design may be improved, and whereby there will accrue a distinct professional and financial advantage to the experts. Once this system is fairly tried it is hard to believe that it will not gain general favor. The Illinois State Water Survey hopes to promote its introduction by demonstrating, if possible, in a few specific cases the advantages that will result.

Note:—The writer desires to acknowledge indebtedness to Messrs. Metcalf and Eddy, Mr. Robert Spurr Weston, Mr. Wynkoop Kiersted, Mr. F. A. Barbour, Dr. Edward Bartow, and Mr. James M. Caird, for valuable suggestions.

DISCUSSION.

John W. Alvord, M. W. S. E.: I am sure we should appreciate it, in every line of endeavor, if things could be prudently run with proper forethought, as Mr. Hansen has indicated he would like to have the small waterworks matters run. The picture which he draws of the average small waterworks is unfortunately all too true. I think perhaps there might be many instances cited which he has not mentioned which would make the condition of the average small waterworks even worse than he has pictured it.

There is a great deal of human nature in a small town and there is a great deal of human nature in the superintendent or owner of the small plant—ambitious human nature; and if there is any one thing in the world that the average man likes to believe it is that he was born an expert at engineering.

I might illustrate this with a little incident that amused me the other day. A gentleman came into my office from a small suburb of Chicago, wherein resides one of the best waterworks engineers in

this country, an honored past president of this Society. The gentleman said that the town trustees had asked this engineer for advice, and they had been told by him that they ought to have a new well, which would cost, with its pump, about \$14,000. "Now," he said, "some of us believe we ought to fight that proposition. We want you to overhaul his plans and tell us how to stop this thing. We may not get any water out of that well at all."

I asked for the name of the engineer, and it was given me. I then said, "Well, I will tell you what you ought to do. You ought to go back and vote for those plans and say nothing more about it. He is a well-known engineer, that is, well known outside of the town where he lives."

He thanked me somewhat earnestly. I am not sure which was the greater surprise to him,—that they had a widely known engineer in their little town, or that I passed up a fee, all of which illustrates the old saying that "A prophet is not without honor save in his own country."

We have to contend against much of that sort of thing, the ability to classify us, and a lack of appreciation of what the consulting engineer is for. Very few people, I think, realize what the consulting engineer is good for anyway. I know my neighbors speak of me as a man who is much on the road traveling, and while once in a while, in my feeble and inefficient way, I try to tell them what I do to earn a living, I know that deep down in their hearts they think I sell waterworks supplies or something of the kind.

Once in a while I tell a good story on my better half, who was very much surprised, just after we were married, to find that I had anything to do with sewers. "Why," she said, "I thought nobody but the very dirtiest men had anything to do with sewers."

So we have to deal with much lack, in the way of a label which the people understand, and I am afraid the world will have to wag on quite a time before the average small water plant, even in groups, employs an expert who, as they say, gets off the cars.

Benezette Williams, M. W. S. E.: Mr. Hansen has covered the ground quite thoroughly on this small waterworks business. I will simply say that I have run across waterworks considerably larger where pumps were leaking 50% of their recorded capacity, that is, their displacement capacity.

W. H. Finley, M. W. S. E.: I would like to ask some of the waterworks experts whether the inefficiency in these smaller places and plants is any greater than it is in some of the large cities.

It has been said that this matter and everything of that sort is left largely to politicians in small places. I suggest that the waterworks experts go into politics and run the thing themselves.

Burton J. Ashley, M. W. S. E.: There seems to be springing up the necessity for another kind of an engineer, termed an efficiency engineer. The demand seems to come from industrial institutions. In thinking over the places into which he would fit very naturally,

it has occurred to me that the field is broad and that this demand is going to increase as the necessity of knowing whether the various manufacturing plants, waterworks plants, sewage disposal plants, plants of any description, are being managed or run as efficiently as they should be.

At this time, but a few miles away from the city of Chicago there is employed an efficiency engineer from the East, who is testing and proving out the efficiency of all the mechanical and operating departments of a large and well known industrial plant, and is paid a large sum for his labors. His labors and reports are expected to be of such interest that one of our well-known periodicals has its staff there watching the operations in order to publish an article upon the workings and usefulness of an efficiency engineer.

It seems to me that the time is likely to come when an expert of this character will fit into place and be of use under the conditions which have been recited by Mr. Hansen in his paper. It may not be in our day and it may.

F. E. Davidson, M. W. S. E.: I have been much interested in listening to Mr. Hansen's paper. I think we have to consider that the situation in the small town today is a political one, and as long as we have a political form of government we are going to have conditions as described in the paper. It seems to me, however, that the idea of the commission form of government, which has proved so successful wherever it has been tried, might result in bettering conditions. We must take the managing body out of party politics before we can hope for a betterment of conditions in the management of waterworks in small towns. They are controlled today by politicians, absolutely regardless of the size of the city. If we can get small cities to adopt the commission form of government, put the government in the hands of three or five men—not a partisan body, but business men—and give them absolute control, then there is some hope for the engineer having control of the small waterworks.

Bion J. Arnold, M. W. S. E.: I am not expected to speak on this subject, I suppose, tonight. The principal reason I have to give for speaking upon it is that I do not know much about it; but knowing that a man sometimes makes a better speech about something of which he knows little, I venture to make a few remarks.

It has been my fate to be one of the organizers of a society, or rather one of those drafted to be among the first directors of a society known as the Efficiency Society, and in that connection, of course, I have learned something about the qualifications of an efficiency engineer and the public opinion of efficiency engineers; at any rate, the opinion as formed by some parts of the public.

I believe, as one of the speakers has said, that there is a field for the qualified efficiency engineer in this country, and I want to say that I make no claims to belonging to the class known as efficiency engineers, because my field is an entirely different one.

It is a fact that the title of efficiency engineer is to a certain extent under suspicion from the fact that so many men have gone into the calling and called themselves efficiency engineers who have been unable, when given an opportunity, to effect economies,—to produce efficient results. Therefore they have been more or less discredited in certain directions. I know of some very efficient, able efficiency engineers. I have no doubt it is one of these gentlemen who is undertaking the task that has been outlined here tonight, although I do not happen to know which one it is.

I know there are men who are qualified for it or men who will go into this calling with the sincere purpose of qualifying themselves for the work before they undertake important work. There is no doubt in my mind but what they will prove a benefit to themselves and to the country, because there is a field and a large one.

As to the qualifications for such a position, I think too many of them have qualified—and evidence of this has been shown in the correspondence which has been received by this Efficiency Society—in a similar manner to a young man who grew up in my town. He was a lad in knee trousers when I left home, an ingenious lad, belonging to an ingenious family. He never stuck to anything very long, but he was ingenious enough to pick up almost anything and make a fair attempt at doing it, though he never did it very thoroughly or efficiently. The lad, as I say, was in knee trousers when I left home. Some years afterwards I was living in St. Paul and was at that time mechanical engineer of a steam railway. This lad came into my office to see me,—a fine looking fellow, dressed well, and apparently very prosperous. I said to him, "James," (his name was not James) "you seem to be doing well."

"Yes, sir, finely."

"And what are you doing now, James?"

"Oh," he said, "I am a plumber."

I said, "How did you happen to get to be a plumber?"

"Well," he said, "it was this way, B. J. I went out to ——— a couple of years ago, and looked around, and I saw only two plumbers' shops in the town, and I thought it was a good place to start a plumbing shop, and I said to myself, By-Gosh, I'm a plumber, and I rented a vacant store and have been a plumber there ever since."

While his ambition was good, his execution was poor, and in order to make the anecdote teach a useful lesson, I am compelled to say that he went into bankruptcy two years afterwards. He, however, learned his lesson and is today an efficient and successful traveling salesman for one of the large plumbing establishments of the country.

Eugene A. Rummeler, M. W. S. E.: Mr. Hansen made a rather sweeping statement in regard to the inefficiency of small water plants. I presume the instance I am about to mention is an example of the kind of exception that proves the rule. I refer to the North Shore suburb of Winnetka. We have our own water and

light plant. It started from a very small beginning, and has entirely paid for itself. It has no indebtedness and it clears for the village about \$18,000 or \$20,000 a year. I think it is managed on a very efficient basis. The managing engineer is well paid and the plant has, therefore, to some extent, become a source of temptations. They try from year to year to overturn the present management so as to be able to appoint some cheap politician in place of the present managing engineer. I presume that if that should ever happen the only way we could have efficiency there would be to have an efficient consulting engineer.

It happens that tonight we have with us Mr. Frank E. Herdman, the managing engineer of this plant, and I wish the president would call on him.

President Reichmann: Mr. Herdman, we shall be glad to hear from you.

Frank E. Herdman: There is not much to say about our water and light properties except that we have tried to operate them on a strictly business basis, and to do this we have kept politics absolutely out of them.

Our water property was put in operation in 1893, the money being raised by special assessment. Since that date all mains have been put in by special assessment, but all enlargements of the property and of the service have been paid for out of the earnings. In 1900 we put in operation our electric property supplying our citizens as well as the street lighting. The first cost was cared for by time warrants, which were afterward paid for out of the earnings. In 1909 we took up the problem of rebuilding and enlarging these properties, which we have done on quite a large and permanent basis without incurring any indebtedness other than for the new intake, the new building and machinery all being paid for out of the earnings.

Our water rate is 15c per 1,000 gallons with a minimum of \$1.00 per quarter, all consumption being metered. Our electric rates are 11c per kw. for light and 8c for power, with 50c minimum for light and 50c minimum per connected horse power per month for power. The village has had fire protection free from cost, and street lighting at a nominal cost.

We try to watch the little things and to maintain an efficient operation, and I think the results show that we have. We feel that in a small way we have demonstrated that a municipal property can be successful, and a satisfaction and benefit to the community served. We have recognized the curse of politics and have kept free from it.

W. H. Finley, M. W. S. E.: I think that the success of the water plant and electric light plant at Winnetka is due largely to the fact, as the last speaker said, that there has been no politics in it. It also bears out the remarks of a previous speaker, Mr. Davidson, as to

the benefits that might be derived from the commission form of government.

Winnetka, you know, is a peculiar little North Shore village. Nearly everybody that lives in it has business here in Chicago. They have a feature in Winnetka that they have in very few other towns or villages, and that is, the old New England town meeting. They get together every once in a while as a sort of large family, and they keep Mr. Herdman and the others straight, whether they want to be or not.

Having lived in that village some eight years, I am fairly familiar with the growth of it, and I wish to endorse what Mr. Herdman said about it. I have always attributed the good state of things in Winnetka to the New England town meeting.

C. C. Saner, ASSOC. W. S. E.: In regard to eliminating politics by changing to a commission form of government, I believe, to a certain extent, such a result might be accomplished,—that is, the appearance of politics will be missing, but the same element that controls politics will still keep control of the situation. This element is the local business men, who aim to control such matters through an organization, which you find in almost all towns today. These organizations are the town trusts formed for the purpose of protecting home industries and thereby mulcting the population of the city at large. It is a condition that exists and controls today, and one for which I am not prepared to suggest a remedy unless some of our national laws control.

I agree with every word in Mr. Hansen's paper, but I believe that if an engineer would go into a city and really try to put a waterworks plant on an efficient basis he would have a very hard battle on his hands. Should he try to buy coal on the B. t. u. system he is in trouble with the local coal dealers. If he tries to buy tools on a competitive basis he is in trouble with the hardware dealers. This is true all the way down the line. The matter would be taken up with the local "trust" and the necessary pressure brought to bear to remove the engineer who is disturbing the old antiquated methods of conducting business.

As to the efficiency of plants in large cities, I am not in close touch with any except the one in Chicago. Since none of the representatives of the department are present I will take the liberty of defending them. I believe that Chicago is fortunate in having some of the best engineers in the country in its service. The City Engineer, Mr. John Ericson, has worked for years to put the Chicago waterworks on an efficient basis. He now has a staff of assistants of whom any engineering organization could well be proud. Specifications are made out for *all* material purchased for this department. All material is tested in the city laboratories and the contractor held strictly to the specifications. I doubt if any railroad entering Chicago can show as efficient conduct of their purchases as the city. As to politics entering into the working of the water depart-

ment, there is certainly some indication of this; but does it enter there any more than in any of our public service corporations or railroads? I believe that less politics enter into the operation of the water department of Chicago than in any other municipally-owned waterworks in Illinois.

W. W. De Berard, M. W. S. E.: Last summer when I was in the Rocky Mountains, about 50 miles from civilization, a long message was received asking if I would name a young man who could "tune up" a filter plant. It seems that a plant of about 4,000,000-gallons capacity had been purchased by a company owning in the same city the water and light works. A filter company had obtained the contract for filters through the purchasing agent, who had been ordered to go out and buy "one filter plant." On completion the filters had been turned over to the pumpman or to the electric light engineer, but the plant would not run efficiently. The operating company then went down the line of their force until they got to a hydraulic engineer, who came to me with a message, asking if I could suggest somebody to put the plant on its feet. I racked my head for some time and finally suggested a man they should have had on the job from the first. The other day he came into the office and told me the plant had been running for two months previous to his seeing it, and during all that time no floc, or precipitate, had ever been obtained from the coagulant. Somebody had dropped the remark that perhaps half a grain of alum was sufficient; therefore never more than half a grain went into the water. The new man immediately increased the applied alum to eight-tenths of a grain and got a beautiful floc. This plant had been running for two months time, during which the company practically threw away all the money paid out for alum, simply because an intelligent operator was not in charge. The plant was a good commercial plant, but it needed a friend who understood its limitations. Many other things, such as loss of head gages, rate controllers, wash water regulation, and air application were soon put into working order, while the original force was taught how to get service out of the installation.

Andrews Allen, M. W. S. E.: I just want to say one thing, in very general terms, and that is, that *all engineers ought to be "efficiency engineers."* This line you try to draw between "construction" and "operation" engineering is, to my mind, dead wrong. The engineer must keep in touch with the operation of the plants he designs, or he cannot be a good designing engineer. He cannot design correctly unless he knows how to operate, and if he does know how to operate he ought to be an "efficiency engineer." Some of us may be "efficiency engineers" and some "inefficiency engineers" according to the results we accomplish, but you cannot tell to which class an engineer belongs by the sign on the door of his office.

Benezette Williams, M. W. S. E.: I want to endorse what our

past-president, Mr. Allen, has said: I cannot conceive of an engineer being really competent to design and put into operation any plant, without his being the most competent person to conduct it for efficiency, other things being equal.

Of course, there are other qualifications than mere engineering ability requisite to efficiency in the management of a public utility, but this is paramount either for the manager or his assistants. The designer should be the one best qualified to bring about favorable results.

There are some things to be said about politics. Politics is made to carry many sins for which it is not responsible. It is too often made "the goat" for all of the shortcomings of human nature. Party politics is not a feature in the affairs of most of the small towns, or at least not in many of them. Elections are decided across political lines, but human nature comes into play just the same. Officeholders shrink from acknowledging any lack of qualifications for any duty however foreign to their experience and training, and their manifest delinquencies are not so much related to politics as to personal pride, or to personal likes or dislikes. Often the self-sufficient business man plays an important part, as suggested by one of the speakers this evening. Hence, it seems to me that politics is made to carry too great a burden,—a burden often due to the shortcomings of human nature rather than to politics.

CLOSURE.

The Author: I feel that Mr. Alvord takes a rather gloomy view of the situation. When we see so much inefficient management going on around us we cannot sit idly by and let it continue, merely because human nature is apparently not correctly constituted. This is especially true of a state official having to deal with waterworks, like myself. While I do not expect the improvements described in my paper to be brought about in a day, I think we ought, nevertheless, to recognize the evil that exists and make proper efforts in the right direction.

Engineers in general practice can do a great deal toward securing expert supervision of small waterworks by simply offering their services or (whenever a favorable opportunity presents itself) by making a contract whereby, after the construction work has been completed, the engineer will be retained for a year to operate the plant. This latter is actually done frequently in connection with waterworks installations.

We are even now making some progress, especially in connection with water purification. Engineers who design water purification works recognize that those works cannot be successful unless properly managed, and they have formed a habit of laying unusual stress on this point. And I think that Mr. Alvord himself, in connection with his Evansville, Ind., filter plant, would have put up a very good fight if the authorities had not agreed to employ a

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man technically trained and reasonably competent to operate that plant under his general direction.

The consulting engineer, by virtue of the fact that "a prophet is not without honor save in his own country," is able to accomplish a great deal in these local communities, whereas the local man cannot. They may know the local man too well. The engineer has an entree that the local man cannot acquire.

No doubt human nature figures to some extent in the problem of an engineer, but to my mind this emphasizes the necessity for a little human nature engineering. It is often possible by tactful dealing with local officials who regard themselves as knowing everything, to accomplish a great deal with them. For example, allow them to believe *they* are the ones who are responsible for good results. Nor have I ever heard of an engineer losing his own reputation by such tactics.

I purposely left out the term "efficiency engineer," because I did not contemplate that this kind of work was to be taken up by a separate class of engineers. In that connection, I wish to fully endorse Mr. Allen's remarks that it is the man who designs plants who is the man that ought to take up the matter of operating them, because the two go hand in hand. A man cannot design plants properly, unless he can operate them properly.

I wish to make an apology in connection with Winnetka. I should have mentioned the Winnetka waterworks as one of the notable instances where a small waterworks plant is being properly operated, and that is due to the fact that they have a regularly employed expert to operate it. Winnetka, however, must be recognized as an exception to the general rule, inasmuch as it is a community of unusually intelligent people and the conditions are unusually favorable for a broad-minded handling of municipal utilities. It is quite unlike the ordinary community and I do not think you can induce the ordinary small community to engage regularly the services of an expert. It looks like the expenditure of too much money. Yet small communities may have much benefit of expert advice for a comparatively small sum by employing an outside consulting engineer.

I would like to say a word or two with reference to municipal governments. It is true that the average municipal government is such that it is exceedingly difficult to introduce efficient methods, but that is a fact that is being universally recognized nowadays and these governments are being improved in many ways, and we may anticipate further improvements. Therefore, why not go ahead with our propaganda of advocating the employment of consulting engineers in connection with operation, and keep pace with our new opportunities?

THE YIELD OF A KENTUCKY WATERSHED

(A TWENTY-SIX YEAR RECORD.)

GEORGE L. THON, M. W. S. E.

and L. R. HOWSON.

Presented April 21, 1913.

West of the Allegheny Mountains, municipal supplies from impounded rainfall are quite rare, and information is lacking from which the yield estimates can be made with accuracy. In the East, the cities of New York and Boston are thus supplied, and records are available covering periods of 25 to 30 years. These records have been the only available guide for estimates by those living in the West, and have been used with corrections for difference in climatic conditions, rainfall, and run-off. This method of securing a water supply from impounded rainfall, is, however, used extensively by railroads in many localities on account of its softness, even where water is plentiful.

The city of Lexington, Ky., derives its water supply from such impounding reservoirs located on Little Hickman Creek about three miles southeast of the city.

The growing demands of the city have recently demonstrated to the water company that an additional supply must be provided. To secure this additional supply the development of the adjoining watershed, East Hickman Creek, was contemplated.

In the consideration of this problem the comprehensive records kept by the water company on the Little Hickman watershed since the installation of its plant in 1885, furnish data upon which can be based an accurate estimate of the yielding capacity of the watershed which it is now proposed to develop.

The original reservoir, known as Reservoir No. 1, was built in 1885 and was capable of impounding, when full, 103,000,000 gallons, the equivalent of 2.3 in. of depth upon the 2.55 square miles of watershed draining therein. In 1896 Reservoir No. 2 was added by building a second dam across the Little Hickman about 1,500 feet down-stream. The combined capacity of the two reservoirs as governed by Dam No. 2 was 391,000,000 gallons, the equivalent of 6.6 in. of depth on the 3.4 square miles of watershed. In 1903 a third dam was built about 1,500 ft. down stream from Dam No. 2, making the combined capacity of the three reservoirs 814,000,000 gallons, or 10.9 in. of depth on the watershed of 4.3 square miles. Exhibit No. 1 is a map showing the location of reservoirs Nos. 1, 2, and 3 on the Little Hickman, and the contemplated Reservoir No. 4 on the East Hickman watershed.

The drainage area of Little Hickman Creek lies in the heart of the famous Blue Grass Region, draining southerly into the Kentucky River. The country has a gently undulating surface which

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becomes quite abrupt at the creek basins. The top soil is, in general, a clay loam of the residual type formed of the decomposition of the underlying rock and averages about 3 ft. in thickness. The

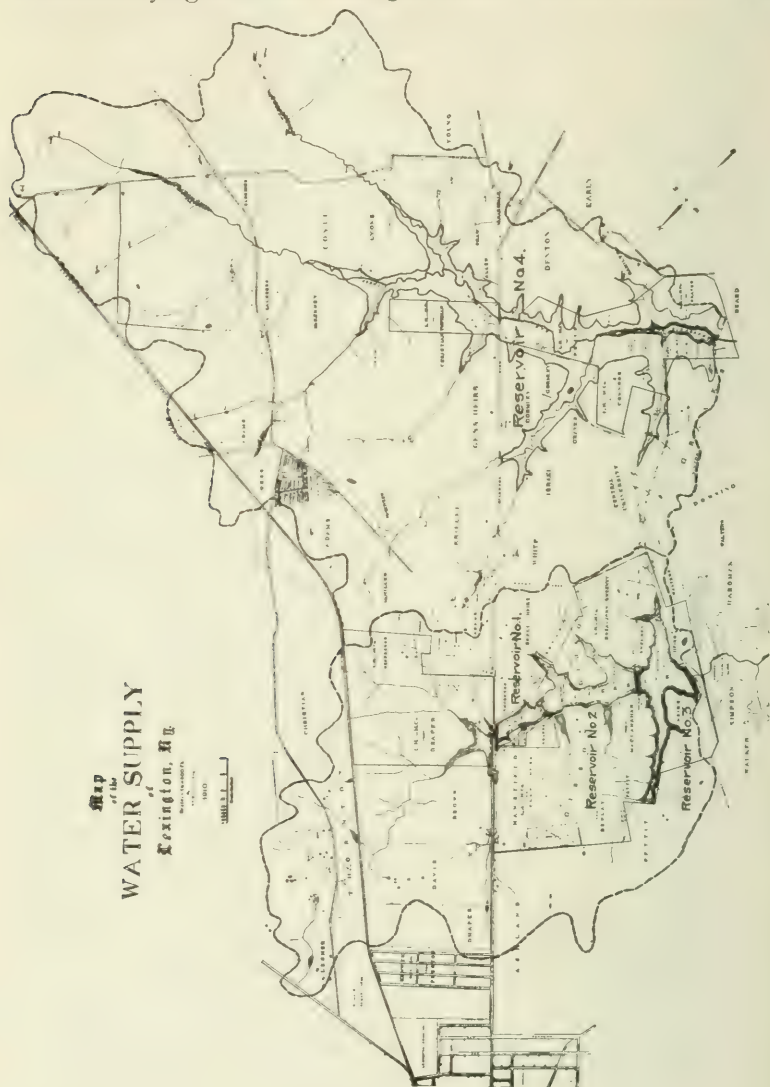


Exhibit No. 1.

underlying rock belongs to the Lexington and Winchester limestone formation of the Ordovician system.

The water company which operates the Lexington Water-

works, early realizing the importance of complete and accurate records, instituted a system of complete daily records covering the observations which were necessary in this study. Among these records, covering 26 years, are observations of rainfall, pumpage, spillway discharge, gauge height of reservoir water level, and some observations on evaporation.

Rainfall:

The run-off on a given watershed being primarily dependent upon the amount of rainfall, it is essential, in a study of this character, to first of all thoroughly investigate the amount and distribution of the rainfall. Rainfall records are much more easily obtained in practically every locality than continuous daily gaugings of run-off.

Rainfall records were collected by the water company at the gauging station on the watershed.

For purposes of comparison with the water company's rainfall records, we have tabulated the summaries of rainfall as reported by the U. S. Weather Bureau at the observation stations nearest the watershed. These observations from 1858 to October, 1872, inclusive, were taken at Chilesburgh about nine miles east of the watershed. In 1872 this station was discontinued and the remaining readings to date were taken at the Government station located in Lexington, no records being available from 1876 to 1886. Comparing these records with those kept on the watershed we find considerable variation in the amounts recorded, the maximum difference being in 1888 when the Government record exceeded the record kept on the watershed by 10 in. In 1899 the readings on the watershed exceeded the Government records by 6.5 in. The average readings at the Government station for the period 1885 to 1911 inclusive, is 42.2 in., which is 3.0 in. greater than the mean annual rainfall for the same period as recorded on the watershed. Some differences in the amount of rainfall recorded at two observing stations located in such close proximity are to be expected, due to inaccuracies of observation, to the relative location, surroundings, and elevation of the gauges. The fact that this locality is subject to severe and frequent local thunderstorms of high intensity further accounts for variations in the records. The Government station* at Lexington reports an average of twenty-one thundershowers for the ten years from 1895 to 1904 during July, August, and September. Such storms also occur during the rest of the year, but less frequently.

Retention:

"Retention" may be defined as the difference between rainfall and run-off; it includes the evaporation from the surface of the drainage area, the seepage into the ground, the water used by

*U. S. Geological Survey Water Supply Paper, No. 233, p. 60.

vegetation and that temporarily held in swamps and lakes. The retention varies greatly from month to month, as the run-off for short periods frequently exceeds the rainfall for that period. During the summer months the losses from evaporation and the uses of plant life are usually large, and the rainfall being comparatively heavy, the retention is usually quite heavy during that season.

Run-Off:

The run-off at a given point on a watershed is that part of the rainfall upon the watershed which reaches the natural water course of the area at the selected point. The run-off of Hickman Creek is based on the following records kept by the Lexington Water Company for the past 26 years.

1st—Wastage over the spillway.

2nd—Water stored in reservoirs.

3rd—Pumpage.

4th—Evaporation from exposed water surface of the reservoir.

The wastage over the spillway was computed from daily readings of head on the spillway channels. These channels are excavated in rock and have an irregular section. The weirs at the entrance to the channel are broad crested and of irregular section. Topographic surveys were made of the three spillway channels and the discharge computed both on the theory of flow in channels and over broad crested weirs; it was deemed advisable to check the wastage in this way on account of the irregularity in the shape of both the channels and weirs. The wastage thus figured is, in our opinion, substantially correct. Inasmuch as these records cover a long period of years, with little available knowledge as to the changes in spillway due to erosion of the channels, washing out of weir planks, and clogging and removal of fish screens, any refinements in the theoretical calculations involved are obviously unwarranted for the purpose of this discussion. As the primary purpose of this paper is the determination of yield and storage capacity required, and as the safe yield is based upon the records of the driest period during which periods there was no wastage, moderate inaccuracies in the measurement of wastage do not materially affect the yield.

The storage draft is computed from daily elevations of the water level in the reservoirs, the volume of which was computed from hydrographic surveys of the reservoir made at the time of this investigation. Storage draft as here considered is the volume of water added or subtracted as determined by the difference in the daily gauge heights.

A portion of the run-off also is withdrawn as pumpage. This amount is computed from average daily records of water pumped by the Lexington Water Company.

To secure the total run-off from the watershed, it is necessary to add to the above component parts an additional amount for the

losses due to the evaporation from the surface of the artificial reservoirs. This evaporation should not be confused with the ordinary evaporation on the watershed which is included in the discussion of "retention."

The evaporation was computed monthly based on the calculated monthly evaporation* at Cincinnati in 1888, using the area of water surface corresponding to the average gauge height during that month. The evaporation record at Cincinnati, Ohio, was used because only fragmentary records of evaporation were kept by the company. The amount of evaporation obviously depends on the area of exposed water surface in the reservoir.

The run-off having been computed as outlined above, we have shown in Exhibits Nos. 2 and 3, the annual relation between rainfall, run-off, and retention. It will be noticed from Exhibit No. 2 that the run-off averages 52% of the rainfall, but varies considerably from year to year. The mean annual rainfall is 39.2 in., and the mean annual run-off is 20.6 in. In finding the mean run-off we have omitted the abnormally high run-off of 1897, amounting to 47 in., as the records of waste over the spillway for this year appear inaccurate. The percentages of the annual run-off, and the annual rainfall occurring each month, are shown cumulatively on Exhibit No. 4. Seventy per cent of the total run-off occurs during the first four months of the year, and during the same period but 35% of the total annual rainfall occurs. During these four months the run-off averages 103% of the rainfall. The percentage of run-off to rainfall occurring each month is shown by the broken line on the same diagram. The monthly relation of rainfall and run-off during the driest year, 1904, as compared with the average monthly rainfall from 1885 to 1911, is shown diagrammatically on Exhibit No. 5.

Comparison with Run-off in Other Localities:

In order to compare the run-off of Hickman Creek with that of other watersheds, we are including Table C, which shows the run-off on a number of American watersheds where records are available for a long period of years.

Yield and Storage:

The yield of any watershed depends primarily upon the following factors:

- 1st—The area of the watershed.
- 2nd—The run-off, especially during a cycle of dry years.
- 3rd—The possible storage capacity which can be developed to store flood waters to be used during dry periods.
- 4th—The evaporation losses in the storage reservoir.

*Turneure & Russell—*Public Water Supply*, p. 57.

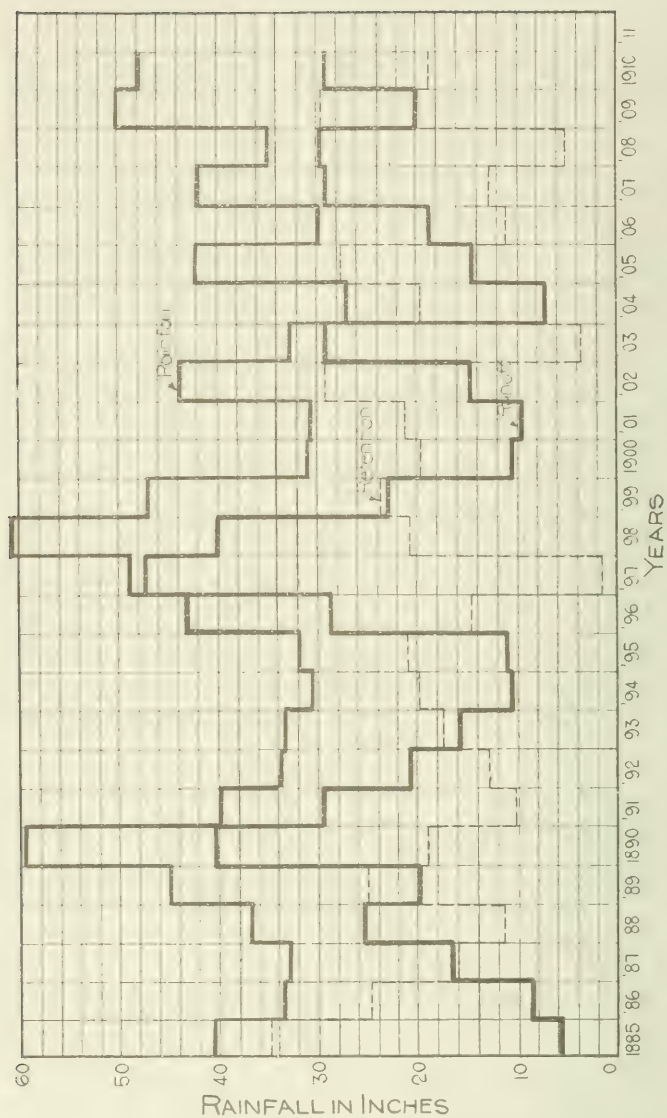
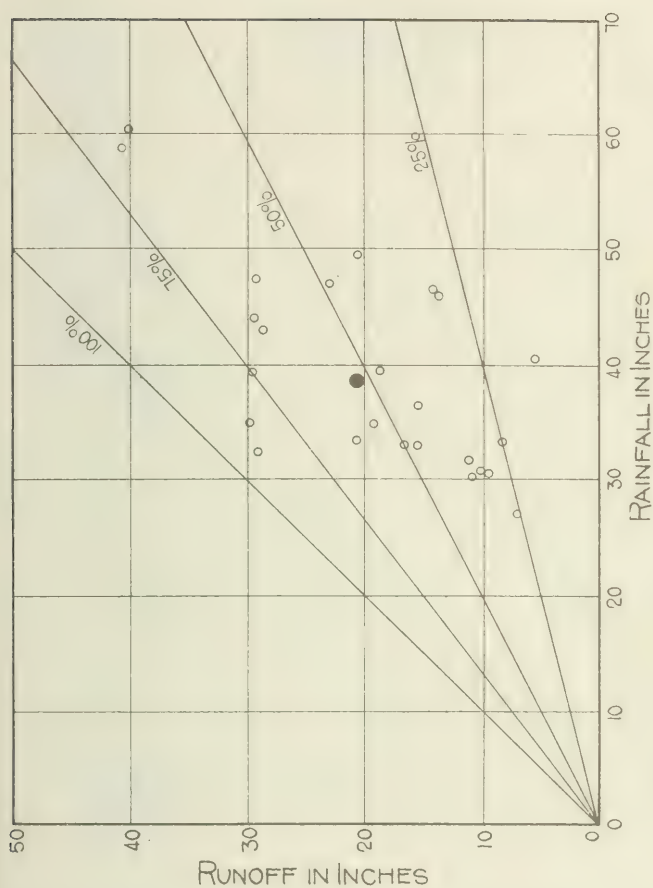


Exhibit No. 2.

ANNUAL RAINFALL, RUNOFF AND RETENTION

Hickman Creek-Lexington, Ky.



ANNUAL RELATION OF RAINFALL AND RUNOFF
Hickman Creek - Lexington, Ky.

Note:—
○ Runoff and Rainfall for one year
● Average Runoff and Rainfall 1885-1911

Exhibit No. 3.

Diagram Showing
 CUMULATIVE AVE. PERCENTAGES OF RAINFALL & RUNOFF
 and
 AVE. MONTHLY PERCENTAGE OF RUNOFF TO RAINFALL

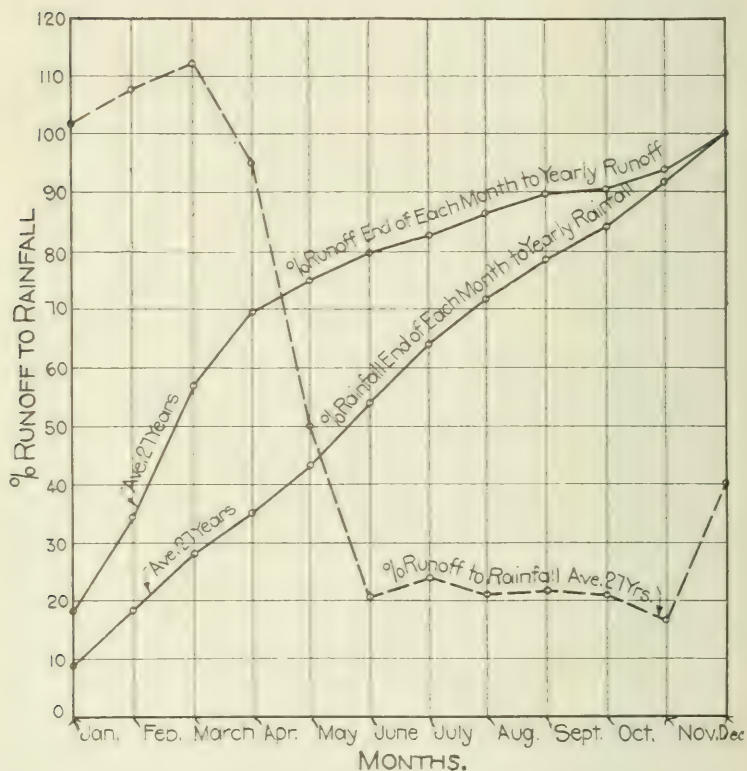
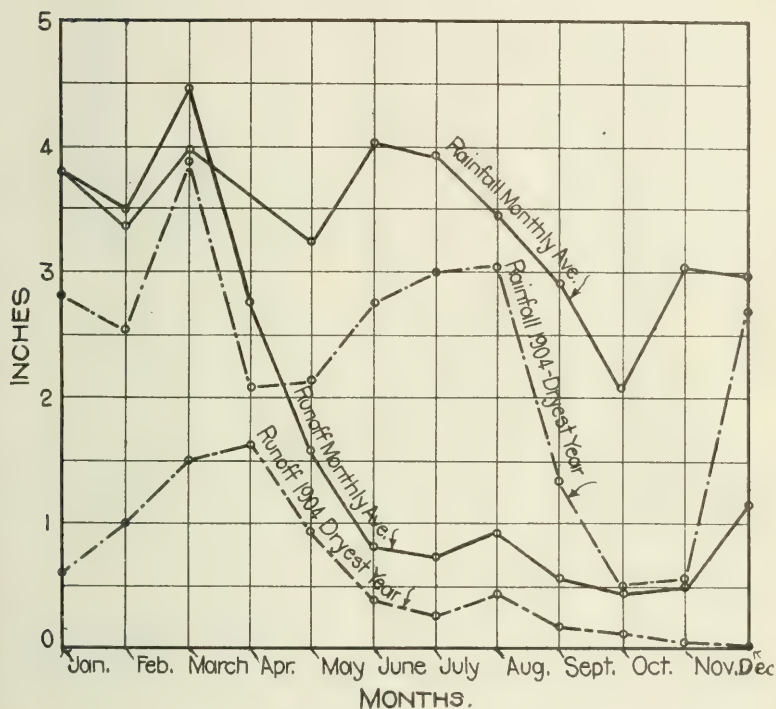


Exhibit No. 4.

RELATION OF MONTHLY RUNOFF TO RAINFALL

For Monthly Averages 1885-1911
& for Dryest Year 1904



Note:—Mean Annual Rainfall 1885 to 1911 = 39.2"
 Ave. " Runoff 1885 to 1911 = 20.3"
 Dryest Year 1904 Total Rainfall 26.95"
 " " 1904 " Runoff 7.14"

Exhibit No. 5.

TABLE C.

Table Showing Run-Offs on Various Watersheds.

	Number of Years Record.	Area, Sq. Miles.	Ave. Annual Rainfall in Ins.	Ave. Annual Run-off in Ins.	Per Cent Run-off.	Annual Re- tention in Ins.
1. Hickman Creek, Ky.	26	4.3	39.2	20.3	52%	18.9
2. Muskegon	8	5826	39.7	13.1	33%	26.6
3. Geneseo, N. Y.	9	1070	40.3	14.2	35%	26.1
4. Croton, N. Y.	25	338	48.4	22.8	47%	25.6
5. Lake Cochituate.	38	18.9	47.1	20.3	43%	26.8
6. Sudbury	25	75	45.8	22.5	49%	23.3
7. Mystic Lake	18	26.9	44.1	20.0	45%	24.1
8. Neshaminy Cr., Pa.	16	139.3	47.6	23.1	49%	24.5
9. Perkiomen Cr., Pa.	16	152	48	23.6	49%	24.4
10. Tohickion Cr.	15	102.2	50.1	28.4	56%	21.7
11. Hudson River	14	4500	44.2	23.3	53%	20.9
12. Pequannock	9	63.7	46.8	26.8	57%	20.0
13. Wigwam Cr., Conn.	9	18	47.4	24.3	51%	23.1
14. Chippewa, Wis.	6	6740	32.5	16.2	50%	16.3
15. Wisconsin-Merrill, Wis.	15	2630	29.67	17.87	60%	11.80

NOTE:

1. Lex. Water Co., 2-3-4-7-8-9-10-11-12; Mead's Water Power, p. 750.
- 4-6. Freeman's New York Water Supply Report, 1900, p. 218.
13. R. A. Cairns, Conn. Soc. C. E. Trans., 1910, p. 52.
14. Mead's Flow of Streams, Wis. Univ. Bulletin, No. 425.
15. C. B. Stewart, Eng. Soc. Wis., 1911.

With the above data it is possible to compute how great a uniform daily draft can be sustained by the natural flow from the drainage area supplemented by the use of such storage as is available.

Area of Watershed as Influencing Yield:

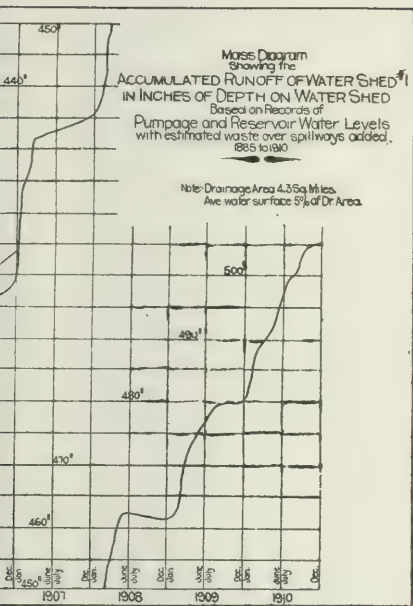
The yield of two watersheds is proportional to their drainage areas, providing other influencing factors such as run-off per unit of area, storage development, and evaporation are equal. This being true, it is convenient for comparative purposes to express yield in inches on the watershed per year, or million gallons daily per square mile.

Run-Off as Influencing Yield:

To determine the safe yield of a watershed, it is necessary to base all computations upon the run-off data for the driest cycle of years covered by the available records. For a correct determination of the driest periods upon which a safe future estimate may be based, records covering the run-off upon the watershed for a number of years are of the utmost value. The records on Little Hickman Creek watershed cover a period of 26 years, including two dry cycles, of about three years each.

Thon—The Yield of a Kentucky Watershed.

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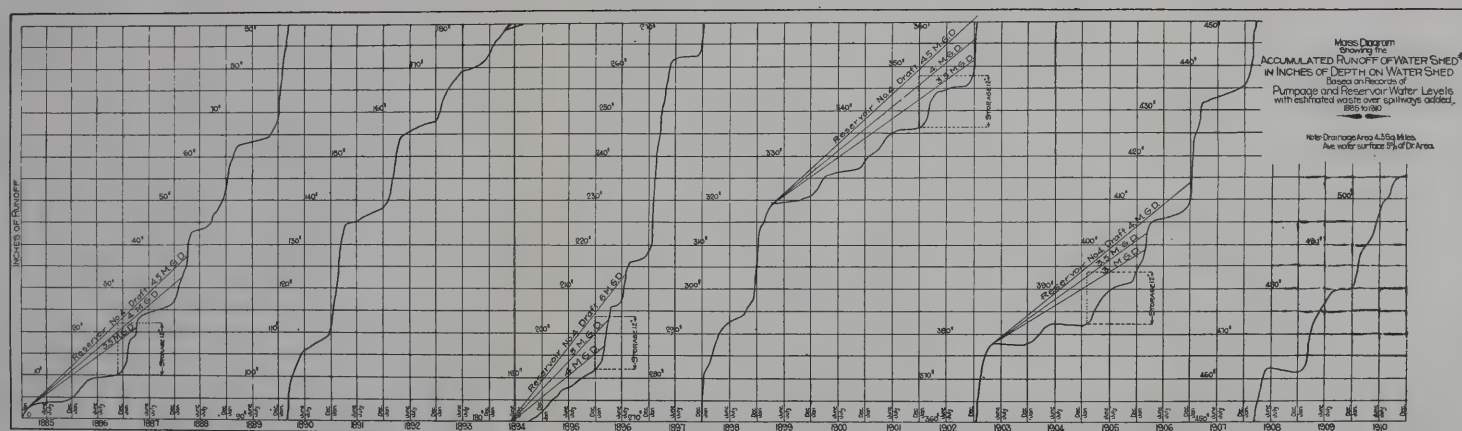


Exhibit No. 6.

Storage:

The storage capacity is of as much importance in the safe yield of a watershed as the area or run-off, and its value consists in augmenting the flow during the dry season from flood waters held in storage, thus providing a more uniform run-off throughout the year. The importance of storage is shown by the following facts. The watershed of Little Hickman Creek with 4.3 square miles does not furnish any flow during dry periods, while with a storage capacity of 814,000,000 gallons it can be relied upon to furnish 1,800,000 gallons per day continuously throughout the driest period occurring in the 26 years.

Computation of Yield:

The yield of a watershed as here discussed is the maximum quantity of water which can be obtained daily throughout the driest cycle of years covered by the records. A complete study of this problem is quite involved and requires careful analysis. The most convenient method of procedure in the study of yield is by means of the mass diagram. This diagram is a graphical, cumulative summary of all the basic run-off data derived from the period of observation. This method of determining yield was first used by Rippl*, and later applied by Desmond Fitzgerald in his studies on the Sudbury†, and by John R. Freeman in his report on the New York Water Supply, March 28, 1900.

We have prepared a mass diagram showing the run-off data on the Little Hickman watershed, Exhibit No. 6. The construction of this diagram required a large number of laborious calculations, but once platted shows by inspection the dry cycles during the period under investigation.

This diagram (Exhibit No. 6), was prepared by plating the aggregate run-off of the Little Hickman cumulatively from the beginning to the end of the record. The data platted are the calculated run-offs month by month composed of the following quantities: Evaporation, pumpage, change in reservoir water levels (plus or minus), and the wastage over spillways. This run-off represents the total flow of the Little Hickman at the site of the reservoir. The total run-off for each month is the summation of the above factors, and is platted cumulatively to form the mass curve with "inches on the watershed," as ordinates.

Referring to the diagram, it will be seen that during the year 1885 the total water furnished by the Little Hickman aggregated about 5 in., the greater portion of this run-off occurring during the early part of the year; the run-off line being practically horizontal during the summer, with the slope again increasing during the balance of the year. In 1886 the run-off was about 7 in., mak-

Proc. Inst. C. E. LXXI, p. 270.

†Trans. Am. Soc. C. E. Vol. XXVII, p. 253.

ing a total run-off of 12 in. for the two years. In 1887 the run-off amounted to 15 in., occurring as usual during the spring, making the total to date of 27 in. In the following year, 1888, the run-off aggregated 25 in., making a total cumulative run-off of 52 in. during the four years.

The measurements of the spillway wastage were not susceptible to so precise determination as the other quantities comprising total run-off, but as no wastage occurred during the driest cycles, the uncertainty of spillway wastage does not affect the conclusions of this discussion.

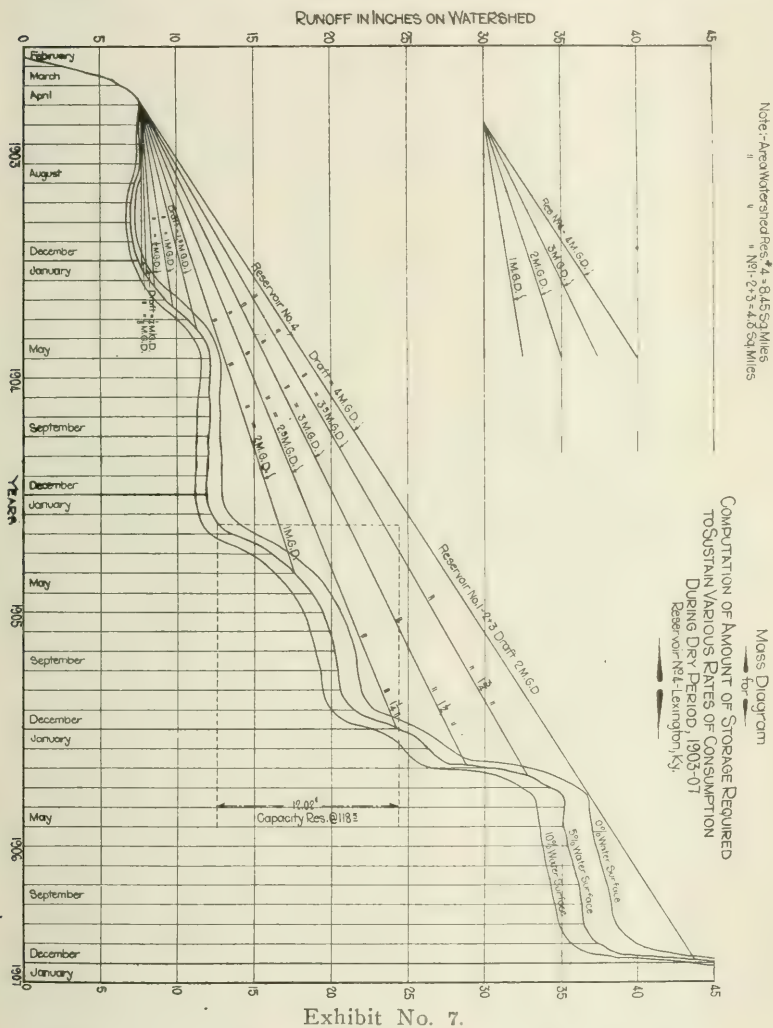
Application of the Mass Diagram:

In any project for the collection of water in storage reservoirs we are principally interested in the dry years, particularly a series of consecutive dry years, for such periods govern the limiting yield of the watershed. It is evident that the factor of greatest importance in the consideration of a watershed for water supply purposes is the maximum daily yield which is capable of being sustained with a given storage capacity during the driest cycle of years to be expected. An examination of the mass curve shows the most unfavorable water-supplying conditions to have occurred in the years 1903, 1904 and 1905, during which time the summer run-off was practically nothing, and the spring run-off from 5 in. to 8 in. only. A more critical examination of this period is made possible by replatting this dry period to a larger scale on Exhibit No. 7.

There are three irregular lines drawn on this diagram, the middle one of which represents the line drawn on Exhibit No. 6 which shows the run-off cumulatively based on an area of water exposed to evaporation of 5% of the area of the watershed. This condition corresponds approximately with the average reservoir conditions on the Little Hickman. The lines above and below on this exhibit represent the conditions as they would be with less or greater water surface, respectively. These lines are of value in applying this mass diagram to watersheds having a different percentage of reservoir surface. The enlarged mass curve for the dry period, Exhibit No. 7, begins in February, 1903, and it will be noticed that preceding the last of April of that year the run-off was plentiful, materially exceeding the amount necessary to fill the reservoirs so that it may be assumed that the reservoirs would be full on the last of April. This condition is verified by the actual record of gauge heights. For the remainder of the year the run-off was very slight, the line being nearly horizontal. Between January and May, 1904, about 5 in. of run-off occurred with no further accretions until February, 1905. During this year, it will be observed that there was a gradual accumulation, showing a small and fairly uniform flow from month to month until the beginning of 1906. Beginning with January, 1906, the run-off increased at a

rapid rate, amounting to 11 in. in the first three months of the year. The total run-off from May 1, 1903, to May 1st, 1906, is about 27 in., or an average of 9 in. per year, or 675,000,000 gallons. The inclined lines on Exhibit No. 7 indicate various rates of draft.

It is now practicable to measure from this diagram the amount



of storage in inches on the watershed which would be required to permit various rates of uniform draft throughout this dry period, by measuring the vertical distance between the inclined draft lines and the run-off curve. Thus it will be seen that the maximum de-

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pletion occurs about the middle of February, 1905, and the storage required on the watershed of the Little Hickman to sustain a flow of 1,500,000 gallons per day would have been 8 in. on the watershed, or with a daily draft of 1,000,000 gallons per day would have been approximately 4 in. on the watershed. Applying this diagram to the East Hickman having a drainage area of 5,403 acres or approximately twice as large as the Little Hickman, we find that with a uniform daily draft of 3,000,000 gallons per day the depletion would have amounted to 8 in. on the watershed. Thus, by giving the sloping lines on Exhibit No. 7 the proper inclination corresponding to the area of the watershed, we can ascertain the amount of storage that would be necessary to supply various uniform rates of draft from that watershed.

Further, it will be noted that for a pumpage of 3,500,000 gallons per day on the watershed of the East Hickman, the water surface would be drawn below the crest for a period beginning May, 1903, and ending in March 1906, practically three years. For the Little Hickman this same period would furnish a yield of 1,750,000 gallons per day and the reservoir would not have filled for the same length of time. It is an interesting fact that the mass diagram checks the actual observed conditions on this watershed. Referring to Exhibit No. 8, the depletion diagram shows the reservoir to have been full in April, 1903, and was gradually drawn down until in February, 1905, it was 65% depleted, then it gradually filled until it overflowed again early in 1906. During this period the pumpage shown directly below the depletion diagram was approximately 1,600,000 gallons per day. This is a check on the accuracy of the mass diagram as a means of estimating storage capacity required.

Yield as Affected by Storage Capacity:

During the period 1885 to 1895, at the time Reservoir No. 1 was in use with a storage capacity of 2.3 in. on the watershed, the annual pumpage varied from $2\frac{3}{4}$ in. to $9\frac{1}{2}$ in. This is interesting, in that it shows that during this period there were years when the total amount of water pumped within a year was equal to four times the capacity of the reservoir. From 1896 to 1902 with Reservoirs Nos. 1 and 2 in operation, having a combined capacity of 6.6 in. on the watershed, there was pumped from the reservoirs an amount varying from $6\frac{1}{4}$ to $8\frac{1}{4}$ in. per year, and from 1902 to 1910 with 10.9 in. on the watershed storage capacity the annual pumpage varied from $6\frac{1}{2}$ to $9\frac{1}{2}$ in. on the watershed. A comparison of these yields with the development of storage on the watershed shows plainly the relative importance of the size of the reservoir to the area of the watershed. During the last seventeen years there were three periods of from two to three years when the reservoirs did not overflow, the lowest reservoir level occurring in 1905 when the storage was about 65% depleted. The development of storage capacity on the watershed, the average daily pumpage, and

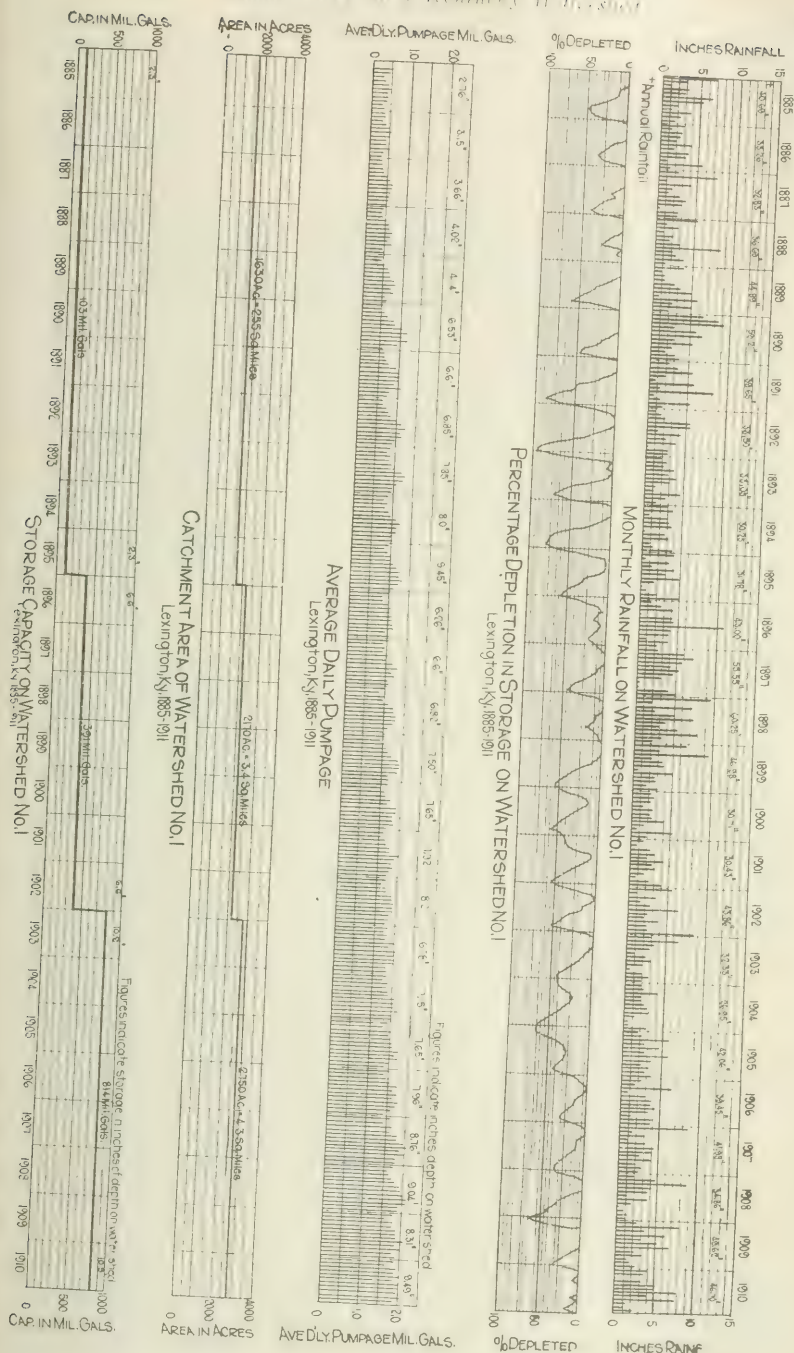


Exhibit No. 8.

the resulting depletion in storage are shown graphically on Exhibit No. 8.

Effect of Evaporation From Reservoir Surface on Yield:

The storage capacity required to sustain various rates of draft

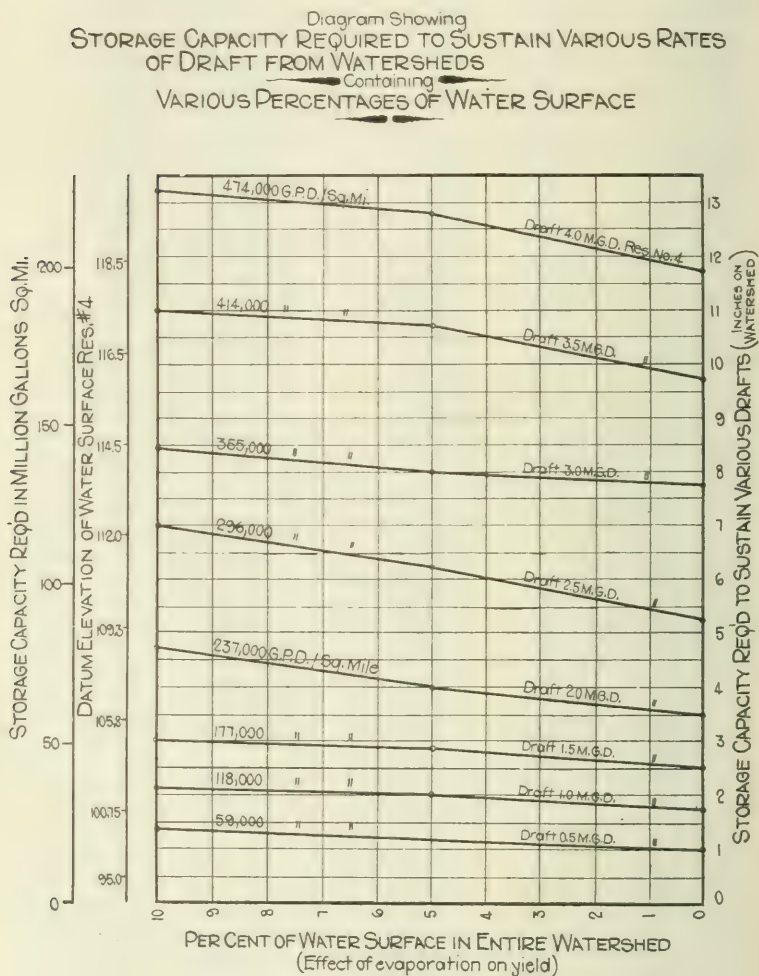


Exhibit No. 9.

from a watershed cannot be conveniently taken from the mass diagram on account of variations in evaporation and pumpage rates. To facilitate this computation, we have constructed Exhibit No. 9, which shows the storage capacity required to sustain various rates

of draft with varying percentages of exposed water surface. This diagram is prepared from the information shown on the enlarged mass diagram. The draft lines as indicated in million gallons daily apply to Reservoir No. 4 on the East Hickman; in order to make

TABLE D.

Comparison of Storage Capacity Required for Various Daily Drafts from One Square Mile of Watershed based on records of Hickman, Croton & Sudbury Watersheds.

Constant Daily Draft Gallons	0 PER CENT		5 PER CENT		10 PER CENT	
	Storage Volume per Sq. Mile. Gallons	Length of Time Reservoir is Below High Water. Months	Storage Volume per Sq. Mile. Gallons	Length of Time Reservoir is Below High Water. Months	Storage Volume per Sq. Mile. Gallons	Length of Time Reservoir is Below High Water. Months
HICKMAN WATERSHED						
50,000	17,000,000	6	20,000,000	9	22,000,000	9½
100,000	25,000,000	10	30,000,000	10	34,000,000	10
150,000	35,000,000	11	39,000,000	11	42,500,000	11
200,000	49,000,000	12	55,300,000	13	59,500,000	22½
250,000	67,000,000	24	78,400,000	25	83,500,000	31½
300,000	94,000,000	31½	106,000,000	32	114,500,000	32
350,000	124,000,000	34	138,000,000	34	147,000,000	34
400,000	158,000,000	34½	171,000,000	35	181,000,000	35
450,000	185,000,000	35	206,000,000	36	215,000,000	43
500,000	222,000,000	43	237,000,000	43	241,000,000	43½
CROTON WATERSHED						
100,000	5,000,000		8,500,000		12,000,000	
200,000	14,000,000		19,000,000		29,000,000	
300,000	30,000,000		36,000,000		43,000,000	
400,000	50,000,000		58,000,000		67,000,000	
500,000	76,000,000		82,000,000		90,000,000	
600,000	100,000,000		110,000,000		118,000,000	
700,000	129,000,000		137,000,000		145,000,000	
800,000	157,000,000		175,000,000		239,000,000	
900,000	285,000,000		340,000,000		396,000,000	
SUDBURY WATERSHED						
100,000	314,000	1.5			15,012,000	6.5
150,000	3,006,000	3.5			19,642,000	7.5
200,000	8,197,000	7.5			25,142,000	7.5
250,000	17,997,000	7.5			33,338,000	8.5
300,000	28,473,000	8.5			43,437,000	8.5
350,000	39,173,000	9.5			54,137,000	9.5
400,000	51,303,000	9.5			66,050,000	10.5
450,000	63,553,000	9.5			78,300,000	10.5
500,000	75,803,000	9.5			90,550,000	10.5
550,000	88,053,000	9.5			105,987,000	21.5
600,000	100,651,000	10.5			134,937,000	21.5
650,000	114,451,000	10.5			163,887,000	21.5
700,000	139,250,000	21.5			192,837,000	22.5
750,000	168,900,000	21.25			221,787,000	23.5
800,000	199,106,000	58.5			297,460,000	92.5
850,000	250,328,000	80.5			380,557,000	107.5
900,000	334,078,000	93.5			465,857,000	116.5

this diagram applicable to similar watersheds, we have converted million gallons daily into million gallons daily per square mile of watershed. From this diagram it is now possible on a similar watershed in this locality, knowing its area and the topography of the reservoir

location, to estimate the probable safe yield for any degree of storage development. We have prepared Table D, which shows the storage capacity required per square mile for 0, 5 and 10% water surface to sustain the constant rates of draft per square mile as shown in the first column. For the purpose of comparison we have included in this table similar information for the Croton watershed as computed from data in Freeman's report on the New York Water Supply in 1900, and for the Sudbury watershed from Turreaure & Russell's *Public Water Supplies*. This information is shown graphically on Exhibit No. 10. It will be noticed that the yield per square mile is greater on the Croton and Sudbury than on the Little Hickman. This difference is due primarily to the following difference of conditions:

1st—The rainfall at the Little Hickman watershed averages but 39.2 in., while the Croton and Sudbury have an annual rainfall of 48.4 in., and 45.8 in. respectively.

2nd—The evaporation on the Hickman watershed averages 52 in., while the Croton and Sudbury watersheds have an annual evaporation of 39 in.

3rd—The effect of the size of the watershed upon the yield is also an influencing factor, inasmuch as the run-off from the large watershed is now uniform in its distribution throughout the year. This is shown by the fact that the minimum flow on the Hickman is *nil*, while on the Sudbury this flow is at the rate of 2.15 in. on the watershed per year.

Effect of Length of Record on Reliability of Yield Computations:

It is evident that in any estimates made of the probable yield of a watershed, the length of the run-off record is of vital importance. This is best shown by referring to the mass diagram, Exhibit No. 6. From this diagram it will be seen from inspection that the driest period occurred from 1903 to 1906. With an available storage equal to 12 in. on the watershed of Reservoir No. 4, it will be seen that a daily yield of 3.6 million gallons per day could be obtained.

To show the importance of the length of the record, let us suppose that the record ended with 1902, covering a period of eighteen years from 1885 to 1902 inclusive. During this period the driest cycle of years occurs from 1899 to 1902. Assuming the same amount of reservoir storage available as in the previous case, we find a daily yield of 4.3 million gallons per day could then be obtained.

If we take the record between 1885 and 1899, the driest period then occurs from 1885 to 1887, and our daily yield with the same storage as before would have been 4.5 million gallons per day.

Selecting the period from 1888 to 1898 from the record, we have eleven years during which time, even in the driest years, 1894-95, a daily yield of at least 5.8 million gallons per day could be obtained, based on 12 in. of storage available.

COMPARISON OF YIELD CAPACITY Hickman Creek, Sudbury and Croton Watersheds

	Hickman	Sudbury	Croton
Ave. Yearly Rainfall	39.2"	45.8"	48.44"
" " Evaporation	52."	39."	39."
Minimum Flow (rate per year)	0.	2.15"	0.
Length of Record	26 Years	25 Years	25 Years
Drainage Area	4.3 Sq. Mi.	75 Sq. Mi.	338.8 Sq. Mi.

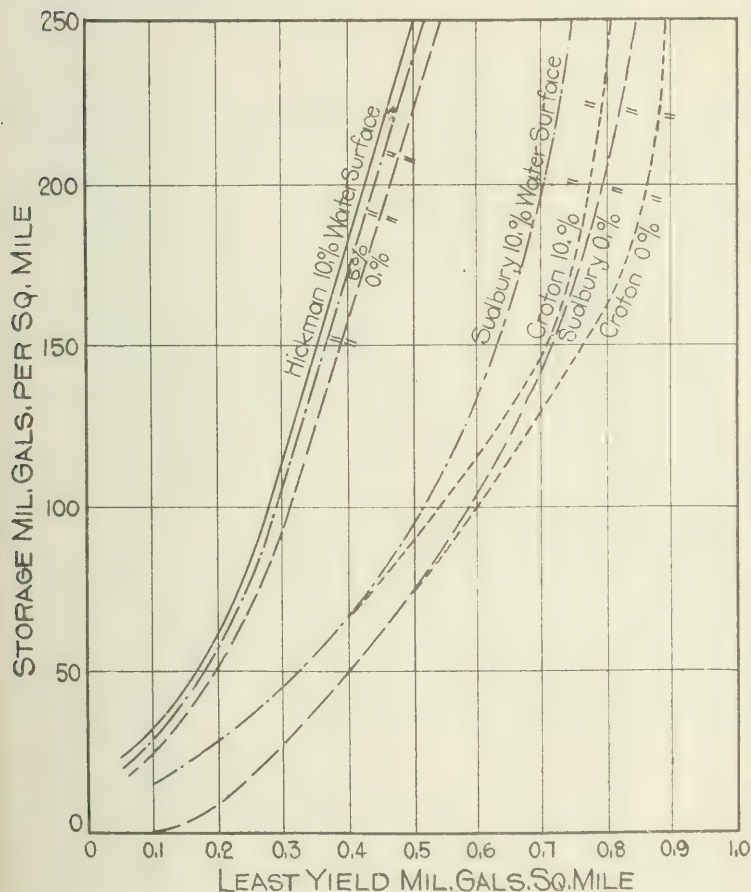


Exhibit No. 10

The above facts show very conclusively that by using a record of short duration, some very erroneous conclusions as to the least yield might result. The following tabulation shows clearly the value of the length of a run-off record in the computation of yield.

Length of Record.	Least Yield During Driest Cycle.	Per Cent Based on 26-Year Record.
26 years.....	3.6 M. G. D.	100%
18 years.....	4.3 M. G. D.	120%
15 years.....	4.5 M. G. D.	125%
11 years.....	5.8 M. G. D.	160%

Even with a record with 26 years of run-off data available, it cannot be safely assumed that a drier period has not existed previous to these records, or may not again occur at some future time.

CONCLUSIONS.

We conclude:

(1) That the maximum daily yield of a Kentucky watershed similar to that of Little Hickman Creek, during the driest cycle of years to be expected once in 25 years, is about 425,000 gallons per day per square mile, with an exposed water surface of 8% of the drainage area and a reservoir capacity of 207,000,000 gallons per square mile available.

(2) That for the above yield, the water level in such a reservoir will be below the overflow for approximately three years.

(3) That the length of the record is of great importance in the determination of yield, as the second driest period in the record indicates a yield 20% greater than the driest period.

(4) That a cycle of dry years and not a single dry year is the controlling factor in the determination of the least yield.

(5) That based on the 26 year run-off records on the Little Hickman, the storage capacity required to furnish various daily yields per square mile is shown in Table D. These data are shown for 0, 5 and 10% exposed water surface.

In that which has preceded, we have attempted to analyze the various steps in the computation of yield on a particular watershed, the run-off records of which were available for a period of 26 years. Although the results obtained may be of benefit in the solution of similar problems in this locality, accurate local run-off data are to be preferred when found available covering a sufficient number of years.

A BRIEF DISCUSSION OF RAINFALL AND ITS RUN-OFF INTO SEWERS.

SAMUEL A. GREELEY.

Presented April 21, 1913.

The determination of the storm run-off for the computation of adequate sizes of sewers, is a problem which involves, finally, three elements—

- (1) The tributary area;
- (2) The intensity of rainfall to be provided for, and
- (3) The maximum run-off into the sewer.

An absolute determination of these elements is, in practice, impossible, and the calculation depends, ultimately, for its solution, upon the judgment of the designing engineer. The engineer's judgment is guided largely by experience, which means, presumably, that the engineer has measured, under known conditions, the rainfall and the run-off. Some engineers whose experience has been large, have sought to express or record their judgment in formulae by which their experience gained in one or more localities might be applied by themselves or others to different localities.

These formulae, or modifications of them, have been used very generally in this country and abroad. The most important of them, transposed to similar terms, are the following:

$$(1) \text{ Hawksley} \quad (1857) \quad Q = C \, r^{3/4} \sqrt[4]{A^3 S}$$

$$(2) \text{ Burkli-Ziegler} \quad (1880) \quad Q = C \, r \sqrt[4]{A^3 S}$$

$$(3) \text{ Adams} \quad (1880) \quad Q = C \, r^{5/6} \sqrt[6]{A^5 S^{1/2}}$$

$$(4) \text{ McMath} \quad (1887) \quad Q = C \, r \sqrt[5]{A^4 S}$$

$$(5) \text{ New York} \quad (1889) \quad Q = C \, r \, A^{.85} S^{.25}$$

In these formulae,

Q equals the total discharge of the tributary area in cubic feet per second,

C equals a coefficient,

r equals a rate of rainfall in inches per hour,

A equals the tributary area in acres, and

S equals the average slope of the area. Modifications of these expressions have been formulated for use in the city of Chicago by Mr. C. D. Hill*¹ and are used by him with success for local sewer designs.

*1. C. D. Hill—*Journal W. S. E.*, Vol. VII, p. 425, Oct., 1902.

The value of these formulæ, and of their relative results, has been often discussed in the past, and the discussion will not be continued here. In accordance with the values of C and r suggested by the authors of the formulæ and given in Table I for ordinary maximum conditions, and with a value of $S = 0.002$, the run-offs for different sized areas have been tabulated in Table II. It would be interesting if some statements were made as to the adequacy of sewers designed and built in accordance with these formulæ.

TABLE I.

Values of C and r ;

Formula.	C	r
1. Hawksley	3.95	1.0
2. Burkli-Ziegler	3.52	2.33
3. Adams	1.03	1.0
4. McMath	3.98	2.75
5. New York	3.26	2.75

TABLE II.

Quantities of Run-off by Standard Formulæ Values of C and r as in Table I.

RUN-OFF IN CUBIC FEET PER SECOND.

Drainage Area in Acres	Hawksley	Burkli-Ziegler	Adams	McMath	New York
20	7.9	16.3	7.6	34.9	59.2
100	26.1	54.4	27.8	126.0	82.4
300	59.5	123.8	69.1	304.0	209.0
500	86.7	180.0	106.0	456.0	323.0
700	113.0	234.0	140.0	576.0	430.0
1000	148.3	306.0	189.5	796.0	583.0

These formulæ themselves evidently do not give absolute or similar solutions for equivalent conditions, and the engineer's judgment, based on a familiarity with the practical workings of the formulæ, must be applied. The element of judgment is required to select

- (1) the proper rate of rainfall,
- (2) the proportion of this rainfall reaching the sewer under maximum conditions, and
- (3) the maximum conditions to provide for. A formula, or method for determining the quantity of storm run-off from these elements, is therefore more or less satisfactory in proportion to the ease and certainty with which it permits or requires the exercise of judgment. Judgment is chiefly based on the results of experience. Therefore what is needed for a truer estimate of the quantity of rainfall and run-off is a large number of actual gaugings covering a sufficient number of cases to afford a reasonable basis for judgment.

The most recent of these standard formulæ was published in 1889. At that time the automatic rain gauge had been used only

for a few years and in a few places, and only one or two accurate gaugings of storm flows in sewers were available. The coördination of formula to actual gaugings was, therefore, not extensive.

There is now available, however, some information upon the intensities of rainfall for different durations and upon the actual storm run-off.

During the past year the Sewage Disposal Division of the Engineering Department of the Sanitary District of Chicago has maintained automatic rain gauges and sewer gauges on several of the sewers within the District. The rain gauges are the standard tipping bucket gauge made by Friez, of Baltimore, and used extensively in the Government service. The sewer gauges comprise a weir built at the sewer outfall, and a continuously recording Bristol water level gauge, actuated by a diaphragm placed in the sewer. This gauge records on a 12 in. disc chart moved by a seven-day clock, the actual head of the sewage passing over the weir at each instant. Similar gauges were operated by Mr. C. C. Saner in the Davis Street Sewer District in Evanston, Illinois. Mr. Saner has arranged the results of his gaugings for presentation at this meeting. The distribution of the rain gauges in the Sanitary District and the location of the sewers gauged is shown in Fig. 1.

The first series of such observations in which gaugings of the rainfall and sewer flow were simultaneously recorded, were made by Mr. Emil Kuichling in Rochester, New York.*² In the description of these observations the so-called "Rational Method" of computing the run-off was first described. This method of computation requires

(1) the determination of the area contributing rainfall to a point on the sewer,

(2) the selection of the average maximum rate of rainfall of sufficient duration to make all parts of this area tributary, and

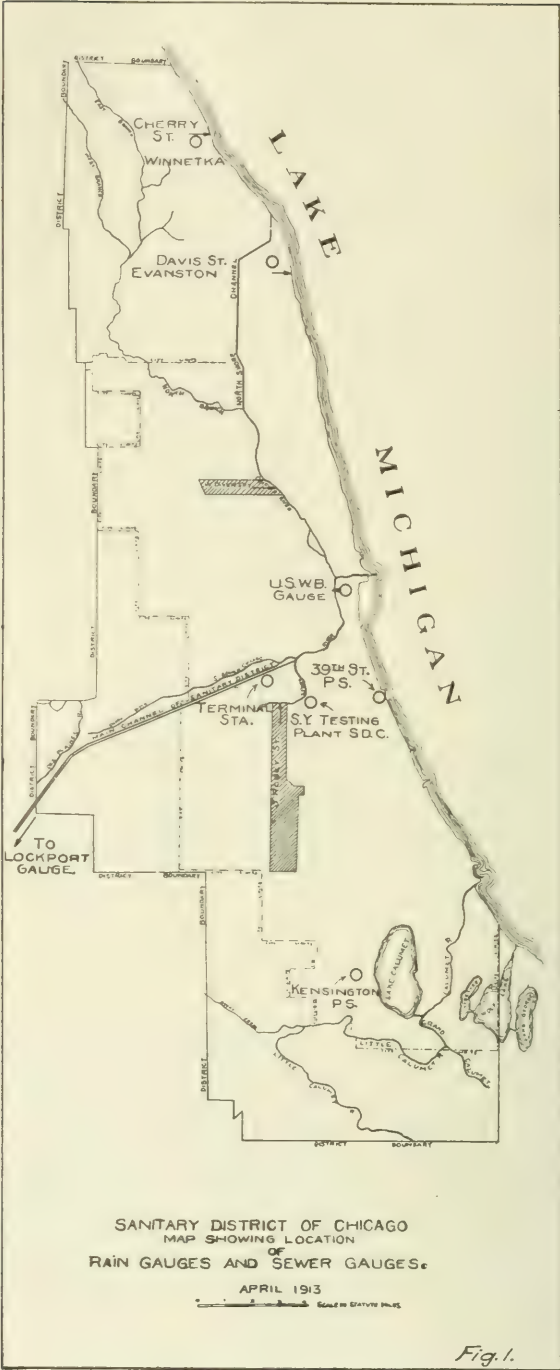
(3) an estimate of the proportion of this rainfall reaching the sewer at the time of maximum discharge—the rainfall and run-off being expressed as rates of flow. The method is expressed by the equation:

$$Q = C r A$$

In this equation, C is the ratio of the average rate of rainfall for a period of time equal to the time of concentration for each particular area, to the maximum rate of flow in the sewer following the period of concentration. The "time of concentration" means the duration of rainfall necessary to make all parts of the area tributary to the given point on the sewer.

The application of this method to any design requires, in the first place, a knowledge of the rate of rain fall to be locally expected for a given duration and for a given frequency or recur-

*². Emil Kuichling—Trans. Am. Soc. C. E., Vol. XX, p. 1, Jan., 1889. September, 1913.



rence. With this knowledge, the permissible interval between surchargings of the sewer can be estimated, and the rate of rainfall for each particular time of concentration selected. In the second place there should be available sufficient records of actual gaugings to afford a reasonable estimate of the value of C for the particular conditions of the design. Now that more data bearing on the selection of reasonable values of r and C have become available, the rational method of design is being used more frequently.

Tables, diagrams, and blank forms for computation have been arranged for use with this method by Dr. Karl Imhoff.*³ Other diagrams are to be found in Fig. 2. At the present time an inquiry into the recorded data available for the determination of r and C seems worth while, and into the factors influencing this determination.

FACTORS INFLUENCING r AND C .

1: *The Rainfall.*

These factors are presented in tabular form as follows:

Factors in the Values of r and C .

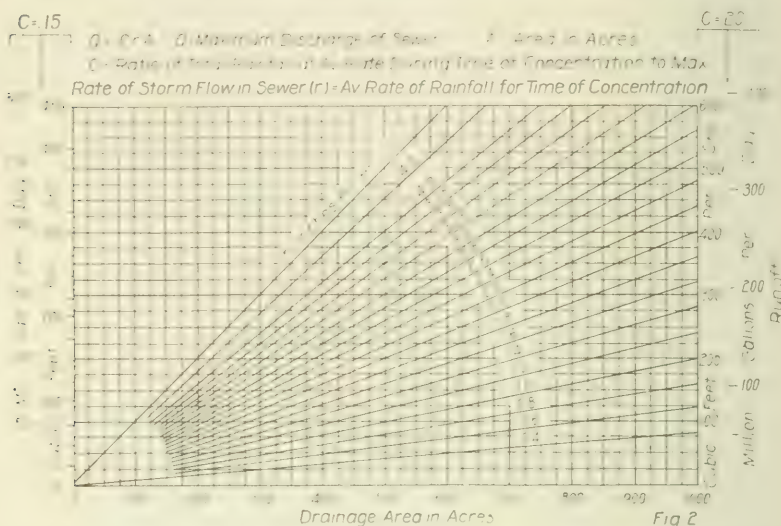
- | | | |
|-----|---|---|
| r | { | <ol style="list-style-type: none"> 1. Size of the tributary area. 2. Slope of the tributary area. 3. Character of the tributary surface. 4. Gutter and inlet facilities. 5. Slope of the sewers. 6. Storage in the sewers and on the ground surface. 7. Effective storm area. 8. Direction of storm travel. 9. Distribution of rainfall in the storm. 10. Value and development of the property served. |
| C | { | <ol style="list-style-type: none"> 1. Imperviousness of the surface. 2. Density of the population. 3. Topography of the tributary area. 4. Character of subsoil. 5. Gutter and inlet facilities. 6. Duration and distribution of rainfall. 7. Distribution of the impervious area. |

The first six of these factors really determine what may be called the effective duration of the storm. The maximum sewer discharge ordinarily occurs when all parts of the tributary area are actually contributing rain water to the sewer. The intensity of the rainfall should correspond in duration to this time of concentration. If the storm duration is longer, a lower intensity of rainfall will follow, and if the storm duration is shorter, only a portion of the area will be tributary. That the first six factors do influence the

*3. Dr. Karl Imhoff—Taschenbuch für Kanalisations—Ingenieure, 2nd Edition, 1912.

time of concentration, and the intensity and duration of the rainfall, is clear. To what extent each factor enters the problem must be estimated for each design.

The effective storm area is an important factor about which very little data have been published. Rainfall records are commonly available for only one point on or near the drainage area. If this area is large, the maximum recorded rate of rainfall of given duration may not be uniform over the whole area. It may be proper to apply a distribution coefficient to the recorded rates of



rainfall. Such coefficients have been proposed by Messrs. Wynne-Roberts and Brockmann*⁴ and are given in Table III.

TABLE III.

COEFFICIENTS FOR DRAINAGE AREAS
— Wynne-Roberts and Brockmann —

Length of Sewer, in Feet	Coefficient
500	0.937
1250	0.900
2000	0.875
3000	0.847
5000	0.802
7500	0.758
10000	0.720
15000	0.660
20000	0.605

*4. Wynne-Roberts & Brockman—Canadian Engineer, Vol. 24, Nos. 7, 8, 9 and 13.

These values are computed from the formula $C = 1 - 0.002 \sqrt{L}$ in which L is the length of the longest sewer line in feet.

There does not seem to be enough data back of these to warrant an unqualified acceptance. Mr. Knichling's observation in Rochester was that storms lasting fifteen minutes might cover an area of six square miles. This statement seems to have been based on careful field observation rather than gauge readings.

In Philadelphia, and New Orleans, six rain gauges are maintained by the city. The United States Weather Bureau also maintains gauges in each city. Therefore these two cities afford an opportunity for measuring the distribution of heavy storms over relatively small areas. Unfortunately the New Orleans records are not published in sufficient detail to bring out this point. Table IV shows records of two storms taken from Philadelphia gauges.

TABLE IV.

DISTRIBUTION OF RAINFALL, PHILADELPHIA, PA., 1911.

City District Number	DATE. July 17th			August 30th		
	Max. Inches	Rate Per Hr. Minutes	Max. Fall in One Hr.	Max. Inches	Rate Per Hr. Minutes	Max. Fall in One Hr.
Second	3.18	10	1.00	0.53	60	0.53
Seventh	...	..	...	1.14	30	0.73
Eighth	2.76	15	1.27	1.57	30	0.98
Ninth	2.83	15	0.91	0.71	30	0.53
Tenth	4.25	10	1.23	0.98	30	0.71
Eleventh	9.44	5	1.79	1.61	30	1.02

The gauges in the second, seventh, and eleventh districts are within a triangular area of about five square miles. The variation in the intensity of rainfall within the area is marked.

Sewer areas may be as large as five square miles. It seems likely, therefore, that more data may warrant the introduction of a distribution coefficient.

On several occasions, records of the same storm have been received on several of the gauges in the Sanitary District. Typical storms were platted and these data bear out the indications of the other records, that storms of severe intensity do not cover the larger drainage areas. These are shown in Figs. 3 and 4.

The influence of the effective storm is controlled somewhat by the direction in which the storm travels. In long, narrow drainage areas, of which there are many in Chicago, this factor assumes importance. The factor is chiefly important, however, in the interpretation of actual rainfall and run-off gaugings rather than in designing sewers for maximum conditions. This statement applies also to the variations of the intensity of rainfall in a storm, but in a different relation. If the heavy rate of rainfall comes after a long continued light rain, the ground will have become saturated and a greater run-off will result.

The tenth factor listed, the value and development of the property served, is one of great practical importance. Much property does not warrant, at least when first sewered, an expenditure for sewers of sufficient size to handle the severest storm. What value of r then shall be chosen? An approximate solution is to

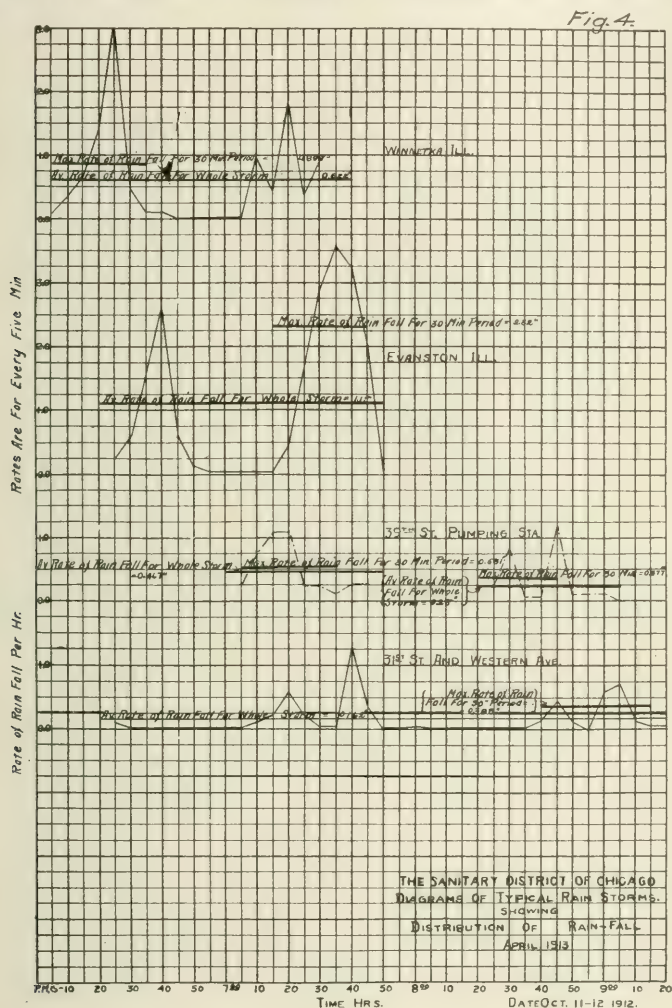


Fig 4

determine a reasonable interval in years between surchargings of sewers based on financial considerations. In some properties a flooding once a year for a short time may not be unreasonable, whereas other properties in which cellar storage of valuable goods is common, should never be flooded. The intensity of rainfall of September, 1913.

proper duration likely to occur once every year or every ten years, as the case may be, should be selected. Fortunately, rainfall records in a limited number of places are now available over a sufficient number of years to indicate the probable recurrence of rainfalls of different intensities and durations. Curves showing the probable rate of rainfall to be equalled or exceeded once in every year, every two years, and every five years in the loop district of Chicago, are shown in Fig. 5.

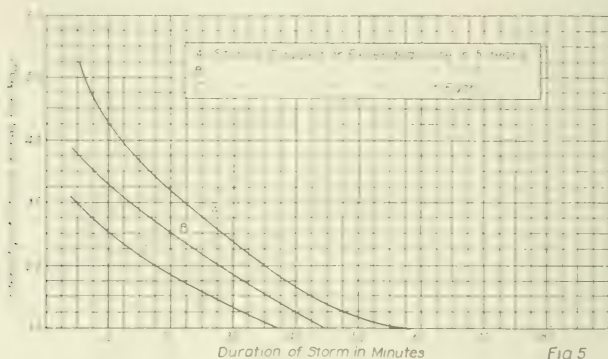


Fig. 5. Curves Showing Probable Rate of Rainfall in Loop District, Chicago.

It should be noted that there are a number of records of storms of long duration and a great intensity which have surcharged apparently well-designed sewers. These surchargings are sometimes due to high water in the river or water course into which the sewer discharges.

TABLE V.

ALBANY, N. Y.

U. S. Weather Bureau Gauge, Rainfall Records, 1899-1912—Fourteen Years.
Courtesy of Theodore Horton.

TABLE FOR HOUR OF RAINFALL AND TOTAL NUMBER OF DOWNSPOURS.

Duration of Down- pour in Minutes	1.0-1.2	1.2-1.4	1.4-1.6	1.6-1.8	1.8-2.0	2.0-2.2	2.2-2.4	2.4-2.6	2.6-2.8	2.8-3.0	3.0-3.2	3.2-3.4	3.4-3.6	3.6-4.0	4.0-4.5	4.5-5.0	5.0-5.5	5.5-6.0	6.0-6.5	6.5-7.0
5	2	2	2	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	2	2	2	2	3	3	3	4	4	4	4	4	3	3	3	2	2	2	2	1
15	2	2	2	2	3	3	3	4	4	4	4	4	3	3	3	2	2	2	2	1
20	2	2	2	2	3	3	3	4	4	4	4	4	3	3	3	2	2	2	2	1
25	2	2	2	2	3	3	3	4	4	4	4	4	3	3	3	2	2	2	2	1
30	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
45	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
50	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
60	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total	16	13	14	19	13	11	12	14	6	7	4	5	7	10	6	5	2	2	..	1

RAINFALL CONSIDERED EXCESSIVE.	
Duration in Minutes	Depth in Inches
5	0.25
10	0.30
15	0.35
20	0.40
25	0.45
30	0.50
35	0.55
40	0.60
45	0.65
50	0.70
60	0.80

Rainfall Data. The chief source of rainfall data in this country is the United States Weather Bureau. Automatic continuously recording rain gauges have been installed by this bureau in all of the larger cities, and have been maintained in many for over twenty years. It would seem advisable for the Weather Bureau to assemble and publish these records up to date, and to make revisions every five, or possibly ten years. The saving effected through more accurate design of sewers would more than repay the public expenditure.

The two most important factors desired from rainfall data are the intensity of rainfall for given durations and the probable recurrence or frequency of severe storms, so that the design of the sewers can be somewhat conditioned to the value and character of the property to be served. Data showing storm characteristics are useful more for particular detailed studies than for the aver-

TABLE VI.

BALTIMORE, MD.

U. S. Weather Bureau Gauge, Rainfall Records, 1894-1907—Thirteen Years.

Courtesy of H. C. McRae.

RATE PER HOUR OF RAINFALL AND TOTAL NUMBER OF DOWNPOURS.

Duration of Down-pour in Minutes.	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0
5	3	6	8	6	9	9	1	2	1	4	1	1	1	1	1	1
10	1	4	3	3	3	2	1	1	1	1	1	1	1	1	1	1
15	4	3	5	5	5	3	1	1	1	1	1	1	1	1	1	1
20	3	3	4	3	3	3	1	1	1	1	1	1	1	1	1	1
25	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	1	2	4	1	1	1	1	1	1	1	1	1	1	1	1	1
35	1	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1
40	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1
45	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
50	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
60	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
80	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
100	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
120	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total	16	25	32	21	21	11	12	9	3	5	1	2	1	1	1	1

age conditions of storm sewer design. Having this point of view in mind, Tables V to XIII have been prepared showing the number of storms of the tabulated intensity and duration which have

September, 1913.

occurred in each particular locality during the period of the observations. From these tables, the probable correct value of C and for the particular conditions of each tributary area can be taken.

2: The Run-off:

The factors influencing the value of C , or the proportion of the rainfall reaching the sewer at the time of maximum discharge, have been given. The first five factors listed influence the selection of the proper value of C for maximum conditions and are also important in the interpretation of actual gaugings. In such gaugings the last two factors listed become important. For a short, quick storm, the value of C will be less than for a severe storm following a long moderate rain. A light rain falling on frozen ground will give a relatively high run-off. In recording a measured value of C , the distribution of the impervious area should be noted. In a long narrow area a smaller run-off will result if the impervious area is mostly at the far end of the area. For maximum conditions these factors are not so important. However, as the determination

TABLE VII.

BIRMINGHAM, ENGLAND.

Rainfall Record, Edgbaston Observatory, 1900-1904—Four Years.

*Lloyd Davies, Proc. Inst. C. E. Vol. CLXIV.*Maximum Duration of Fall
in Minutes.

	Rate of Fall—Inches per Hour—											
	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.5
	Total Number of Storms											
5	20	13	12	9	8	5	5	4	3	2	2	1
10	9	4	3	1	1	1	1	1	1	1	1	1
15	6	1	..	..	..	..	..	..	..	..	..	..
20	5	1	..	..	..	..	..	..	..	..	..	..
25	1	..	..	..	..	..	..	..	..	..	..	..
30	1	..	..	..	..	..	..	..	..	..	..	..
Total	42	19	15	10	9	6	6	5	4	3	3	2

TABLE VIII.

BOSTON, MASS.

Chestnut Hill Reservoir Gauge, Rainfall Records, 1879-1904—Twenty-five Years.

Courtesy of Harrison P. Eddy.

RATE PER HOUR OF RAINFALL AND TOTAL NUMBER OF DOWNPOURS.

Duration of Downpours in Minutes.	1.0 Inch per Hour or Greater.	1.5 Inch.	2.0 Inch.	2.5 Inch.	3.0 Inch.	3.4 Inch.	3.8 Inch.	4.2 Inch.
5	6	3	7	7	3	2	..	..
10	18	21	16	10	6	..	..	..
15	9	6	12	4	2	..	..	..
20	12	10	2	5	1	..	..	..
25	3	1	1	..	..	..	..	..
30	4	2	1	1	..	..	..	..
35	5	3	..	..	..	..	..	..
40	2	1	1	..	..	..	..	..
45	1	1	..	..	..	..	..	..
50	2	..	1	..	..	..	..	..
60	1	1	1	..	..	..	..	..
80	6	2	..	..	..	..	..	..
120	3	1	..	..	..	..	..	..
Total	72	57	42	27	15	6	3	2

TABLE IX.

CHICAGO, ILLINOIS.

Rainfall Records, 1889-1910—Twenty-two Years.

Courtesy of W. W. Mathews.

RATE PER HOUR OF RAINFALL AND TOTAL NUMBER OF DOWNPOURS.

Duration of Downpours in Minutes.	1.0 In.	1.1 In.	1.2 In.	1.3 In.	1.4 In.	1.5 In.	1.6 In.	1.7 In.	1.8 In.	1.9 In.	2.0 In.	2.1 In.	2.2 In.	2.3 In.	2.4 In.	2.5 In.	2.6 In.	2.7 In.	2.8 In.	2.9 In.	3.0 In.	3.1 In.	3.2 In.	3.3 In.	3.4 In.	3.5 In.	3.6 In.	3.7 In.	3.8 In.	3.9 In.	4.0 In.	4.1 In.	4.2 In.	4.3 In.	4.6 In.	4.7 In.	4.8 In.	5.2 In.	5.4 In.	5.8 In.	5.9 In.	6.1 In.	6.6 In.	7.2 In.		
5	5	6	8	8	9	10	5	11	5	7	7	4	4	4	8	2	2	3	3	6	2	1	2	1	3	4	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
10	10	6	4	10	6	5	7	8	8	6	3	7	5	3	3	2	3	2	1	4	1	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
15	7	5	10	5	12	6	4	5	3	4	6	1	1	1	1	2	1	1	1	2	3	1	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
20	12	7	5	2	8	5	2	2	3	2	4	3	2	1	1	1	2	1	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
25	5	5	5	11	4	2	2	2	1	3	2	1	1	2	1	2	2	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
30	3	6	4	2	1	3	1	1	5	1	1	3	1	1	2	1	2	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
35	2	5	1	1	1	1	3	5	2	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
40	3	2	1	1	1	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
45	2	1	1	3	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
50	1	1	2	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
60	2	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
80	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
100	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
120	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

TABLE X.

CINCINNATI, OHIO.

U. S. Weather Bureau Rainfall Records, July, 1897-July, 1912—Sixteen Years.

Courtesy of H. S. Morse.

RATE PER HOUR OF RAINFALL AND TOTAL NUMBER OF STORMS.

Duration of Storms in Minutes.	1.0 In.	1.1 In.	1.2 In.	1.3 In.	1.4 In.	1.5 In.	1.6 In.	1.7 In.	1.8 In.	1.9 In.	2.0 In.	2.1 In.	2.2 In.	2.3 In.	2.4 In.	2.5 In.	2.6 In.	2.7 In.	2.8 In.	2.9 In.	3.0 In.	3.1 In.	3.2 In.	3.3 In.	3.4 In.	3.5 In.	3.6 In.	3.7 In.	3.8 In.	3.9 In.	4.0 In.	4.1 In.	4.2 In.	4.3 In.	4.4 In.	4.5 In.	4.6 In.	4.9 In.	5.1 In.	5.3 In.	5.6 In.	5.8 In.	6.3 In.	
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
45	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
50	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
60	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
70	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
80	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
90	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
100	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
120	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

of the values of r and C depends upon a correct interpretation of the existing and increasing number of actual gaugings, these factors cannot be omitted.

Run-off Data. The only practical way to determine the actual run-off of sewered areas is to measure it, and selections of the value of the coefficient C must be based on a sufficient number of actual gaugings. Below are brief compilations of most of the published records of gaugings of storm flows in sewers arranged in such a manner as to throw as much light as possible on the value of C . The data so far obtained in the Sanitary District are also given. The coefficient C is defined as the ratio,

(1) of the average rate of rainfall for a period of time equal to the time of concentration for the particular area,

(2) to the maximum rate of flow in the sewer following the period of concentration. Gaugings in which the duration of the rainfall was much less than the stated time of concentration, have been excluded, and a few gaugings in which the duration of the rainstorm was greater than the time of concentration, have been included, to indicate the increase in the proportion of run-off as the area becomes saturated.

1. *Rochester Data.**² These data were secured in a scientific

TABLE XII.

NEW YORK CITY.

U. S. Weather Bureau Gauge, Rainfall Records, 1905-1912—Eight Years.

Courtesy of Chas. Saville.

RATE PER HOUR AND TOTAL NUMBER OF DOWNPOURS.

Duration of Down- pour in Minutes																				
	1.0-1.2	1.2-1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	4.0	4.5	5.0	5.5	6.0	6.5	7.0
5	14	8	7	5	3	2	5	1	2	2	1	0	0	1	1	2	1	1	1	0
10	12	1	3	6	4	2	1	3	0	1	0	0	1	2	0	1	0	1	0	0
15	5	5	4	3	4	1	0	0	3	1	..	..	..	..	1	1	..	..	1	0
30	7	5	4	0	1	0	0	0	1	1	..	..	..	..	..	..	..	..	..	..
60	2	2	0	2	0	0	1	..	..	..	..	..	..	..	..	..	..	..	..	..
Total	40	21	18	16	12	5	7	4	6	5	1	0	1	3	2	4	1	2	2	0

manner, all details being carefully worked out and all conditions being fully stated. Automatic rain gauges were not used, but the gauges were read during storms, whenever the intensity appeared to vary.

The records presented in Table XIV are principally taken from Table No. 10 of Mr. Kuichling's original paper. The values of C selected appear to be typical. The percentage of impervious area on each district is not recorded, but a careful description of each

district is given in the original paper. The population per acre for District 1 has been computed approximately from the data given.

2. *New York Data.*^{*5} The record of Mr. Hering's gaugings of the Sixth Avenue sewer, New York, have been tabulated and published by Mr. C. E. Gregory. Mr. Gregory states that the gaugings "were made with a single clock gauge which recorded the depth of flow in the sewers. The water surface slopes, therefore, had to be assumed. Mr. Hering states in his report that conditions were suitable for the safe application of a slope formula, and it may be only a matter of opinion whether or not this was true. The most serious objection is that the automatic gauge from which the rainfall rates were obtained, was two miles distant in

TABLE XIII.

RICHMOND, VA.

U. S. Weather Bureau Gauge, Rainfall Records—Seventeen Years.
Courtesy of Allen J. Saville.

RATE PER HOUR OF RAINFALL AND TOTAL NUMBER OF DOWNPOURS.

Duration of Down- pours in Minutes	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5	5.5-6.0	6.0-6.5
5	4	1	2	3	2	1	1	1	..	0	1
10	3	3	3	3	..	1	..	1	1	..	..
15	1	3	3	1	1	..	1	1	..	..	..
20	1	7	2	1	1	..	..	1	..	..	..
25	2	6	3	2	..	..	..	..	1	..	..
30	3	6	2	..	1	..	..	..	1	..	..
35	2	6	3	..	1	..	..	1	..	..	..
40	1	4	2	1	..	..	1	..	..	..	..
45	3	4	..	1	..	1	..	..	..	..	..
50	3	3	..	..	1	..	..	..	..	..	..
60	4	3	1	1	..	..	..	..	..	..	..
80	2	1	..	..	..	..	..	..	..	..	..
100	2	..	..	..	..	..	..	..	..	..	..
120	1	..	..	..	..	..	..	..	..	..	..
Total	32	47	21	13	7	3	3	5	3	0	1

Central Park, and these rates were checked with the rain gauges on the area for total amounts only."

The tributary area is stated to have been 221 acres, of which 90% was impervious. The time of flow through the longest line of sewer was fifteen minutes, to which should be added five to ten minutes to give the time of concentration. The rates of rainfall for durations corresponding to the time of concentration, are not given, the longest short time storm recorded being for sixteen minutes, and the shortest long time storm being for one hour and fifteen minutes duration. The average results are given in Table XV.

*2. Emil Kuichling—Trans. Am. Soc. C. E., Vol. XX, p. 1, Jan., 1889.

*5. C. E. Gregory—Trans. Am. Soc. C. E., Vol. LVIII, p. 458, June, 1907.

TABLE XIV.

RAINFALL AND THE RUN-OFF INTO SEWERS.

Proportion of Run-off from Rochester Gaugings.

Item	District X	District IX	District XVII	District IV	District I
1. Tributary area	25.12	132.96	92.27	128.67	356.94
2. Population per acre.....	40	26	35	32	20
3. Probable time of concentration (minutes).....	16	23	24	26	44
	T. R. C.	T. R. C.	T. R. C.	T. R. C.	T. R. C.
4. { T=Actual duration of storm.	20 .80*	30 .24*	30 .21*	25 .25	60 .31*
{ R=Average ratio of rainfall for duration stated.	15 .76†	30 .30*	30 .30*	30 .24*	50 .47*
{ C=Percentage of run-off.	15 1.62‡	20 .80*	20 .80*	30 .30*	35 .
5. Average value of C.	33.7	34.3	25.1	19.2	16.7

*Preceded and followed by lighter rain.

†Heavy shower preceded by lighter rain.

‡Sudden shower followed by lighter rain.

TABLE XV.

RAINFALL AND ITS RUN-OFF INTO SEWERS.

Proportion of Run-off from New York Gaugings.

Data	Values of C
1. Average run-off from 13 storms of duration less than 10 minutes...	34.0%
2. Average run-off from 25 storms of duration equal to 10 minutes...	44.5%
3. Run-off from one storm, lasting 13 minutes.....	37.7%
4. Run-off from one storm, lasting 15 minutes.....	69.0%
5. Run-off from one storm, lasting 16 minutes.....	45.8%

These values of *C* are probably too small, because the duration of the storms was less than the time of concentration, and consequently the rainfall was computed as flowing from too large an area, giving a larger volume of rainfall than was actually tributary, and hence a smaller run-off than the true run-off. Mr. Gregory states that in seven of these storms, "the percentage run-off in each storm varies only 5% from the average of 39% of the average rain for 15 minutes (the time required for the water to flow from the most remote part of the watershed); or from 50% if this time be taken as 25 minutes." As a value of *C* to use in computations for maximum conditions, both these values seem low. A value equal to or greater than 69% seems more practicable.

3. *Milwaukee Data*.^{*6} These gaugings were made for a graduation thesis at the University of Wisconsin. They were made on an 8 ft. sewer in Milwaukee during a period of six weeks in the summer of 1898, an automatic float gauge being used. The total tributary area was 1138 acres and was residential in character, containing about 18.5% of street area. The rainfall records were taken from the United States Weather Bureau automatic gauge, and were checked by comparison with a city rain gauge which was read by means of a graduated stick at the beginning, and at the end of each rain and at times of noticeable change in the rate of rainfall. These two gauges were about two miles from each other, and one to two miles from the drainage district. The two gauges agreed fairly well and the writers felt safe in saying that "at least on those rainfalls used in the discussion, * * * the rainfall was uniform over the entire section, and fell with the registered intensity." The results of these gaugings are summarized in Table XVI.

TABLE XVI.

RAINFALL AND ITS RUN-OFF INTO SEWERS.

Proportion of Run-off from Milwaukee Gaugings.

1. Date of storms, 1898—	July 31	Aug. 6	Aug. 2	Aug. 23
2. Duration of rain, minutes.....	30	15	85	25
3. Average rate of fall during this period, inches per hour.....	0.1	0.173	0.28	0.72
4. Tributary area for this duration....	490.0	170.7	1138	421.0
5. Value of <i>C</i>	13.0	19.0	20.0	38.0

*6. Logeman & Nomenson—Eng. News, Vol. XLV, page 408, May 30, 1901.

It is interesting to observe that the percentage of run-off increases with the intensity of the rainfall.

4. *Cambridge, Mass., Data.*7* In 1900 a series of observations of storm flows in sewers was made in Cambridge, Mass. The gaugings were platted by Mr. Freeman and the following data have been taken from his diagrams. The Shepard Street and Sherman Street sewers were gauged. The characteristics of the drainage areas of these two sewers is stated to be as follows:

	Shepard St.	Sherman St.
Tributary area in acres.....	56.5	68.1
Percentage in roof area.....	12%	10%
Percentage in streets.....	24%	18%
Percentage in lawns and gardens.....	64%	72%
Total number of houses.....	155	292
Houses from which roof water runs directly into sewer	80	87
General slope of drainage area.....	.28 per 1000	32 per 1000
General characteristics of soil.....	Sandy	Clay

No statement of the time of concentration is given. For areas of this size it should not exceed twenty minutes, so that rates approximating this duration have been selected in computing the values of *C* given below. The rates of rainfall and the rates of discharge in the sewer are shown by Mr. Freeman diagrammatically.

1. Gaugings made during a long, steady rain:

Time After Beginning of Rain	Av. Rate of Rainfall in Inches Per Hour	Max. Rate of Discharge in Sewer, Cu. Ft. Per Sec. Per Acre	Value of <i>C</i>
<i>Shepard St.</i>			
Feb. 25 2 hrs. 10 m.	0.30	0.07	23.3
3 hrs. 55 m.	0.34	0.13	38.3
5 hrs. 30 m.	0.275	0.15	54.7
6 hrs. 20 m.	0.27	0.16	59.3
May 3 5 hrs. 25 m.	0.43	0.05	13.6
6 hrs. 25 m.	0.56	0.14	25.0
8 hrs. 25 m.	0.30	0.095	31.6
<i>Sherman St.</i>			
May 3 5 hrs. 35 m.	0.43	0.28	65.0%
6 hrs. 55 m.	0.565	0.44	78.0%
8 hrs. 35 m.	0.33	0.33	100.0%

2. Gaugings of typical heavy summer showers:

	Aver. rate of Rainfall in Inches Per Hour	Max. Rate of Discharge in Sewer Cu. Ft. Per Sec. Per Acre	Value of <i>C</i>
<i>Shepard St.</i>			
	1.00	0.32	32.0%
	0.70	0.35	50.0%
	1.80	0.51	28.3%
<i>Sherman St.</i>			
	1.00	0.45	45.0%
	0.70	0.20	28.8%
	1.80	0.70	38.9%

*7. John R. Freeman—Report on Charles River Dam.
September, 1913.

3. Gaugings typical of steady, heavy rainfalls on ground saturated by a previous rainfall:

	Aver. Rate of Rainfall in Inches Per Hour	Max. Rate of Discharge in Sewer Cu. Ft. Per Sec. Per Acre	Value of C
<i>Shepard St.</i>	0.365	0.17	46.7%
	0.15	0.08	53.3%
<i>Sherman St.</i>	0.365	0.365	100.0%

These gaugings show the effect of saturation in increasing the impervious area and the effect of the character of the soil.

5. *San Francisco Data*.^{*8} Mr. C. E. Grunsky, in an elaborate paper on the sewer system of San Francisco, gives the values of C in Table XVII as those used in estimating the required storm water capacity from the rate of rainfall. San Francisco is a hilly city, having relatively steep surface slopes.

TABLE XVII.

Population per acre.	Value of C.
20	30.0
30	40.0
40	50.0
50	55.0
60	60.0
70	65.0
80	70.0
90	73.0
100 and higher	75.0

These coefficients were used in the computations by the rational method in 1899. Mr. Grunsky states, after further investigation, that the quantities of run-off resulting from the use of these coefficients are reasonably close for areas with impervious surfaces, but will probably give too small values for small areas which are only partly pervious.

6. *St. Louis Data*.^{*9} In the article referred to, Mr. Horner gives an excellent description of modern procedure in district sewer design by the rational method. He states that the coefficient C should not be considered the proportion of total rainfall reaching the sewer, but represents the relation between the maximum rate of run-off and the average rate of rainfall, during the critical time. For a district carrying a population of about 40 per acre, and having about 45% of entirely impervious area, he suggests the average values of C given in Table XVIII.

*8. C. E. Grunsky—Trans. Am. Soc. C. E., Vol. LXV, p. 294, Dec., 1909.

*9. W. W. Horner—Eng. News, Vol. LXIV, p. 326, Sept. 29th, 1910.

TABLE XVIII.

Duration of Rain Minutes	Per Cent Run-Off From		Value of C
	Impervious Portion	Pervious Portion	
10	60	20	40%
15	70	30	50%
20	80	35	55%
30	85	40	60%
60	95	50	70%
120	95	60	75%

Mr. Horner suggests that further data will establish slightly lower values for the short times, and greater values for the longer periods. This increase in the percentage of run-off with longer downpours was apparent, also, in the Milwaukee gaugings and is brought out clearly by Mr. C. E. Gregory.*⁵

In designing for maximum conditions, it may probably be assumed that the short intense rainfall controlling the sewer size occurs after a lighter rain which has already saturated the ground, so that the larger values of C should be used.

7. *Birmingham, England, Data.**¹⁰ The gaugings made by Mr. Lloyd-Davies, in Birmingham, are very complete. The sewer discharges were determined by measuring the elevation of two points of the hydraulic grade line just back of the sewer outlet. The rainfall records were taken "by means of three self-registering recording rain-gauges surrounding the selected area, and for several of the heaviest storms, the record from a fourth gauge, in the center of the area, was also used." Three sewers were gauged, a summary of the gaugings being given below. It is stated that the run-off in excess of 100% for the Bordesley St. sewer results from the impossibility of determining exactly the intensity of the precipitation for very short periods. The author gives, as one result of the investigation, that "the storm water discharge from any defined district is directly proportional to the percentage of imperviable area comprised in it."

(1) Moseley Street Sewer:

Drainage area, 312.5 acres. Population per acre, 96.0. Percentage of drainage area impervious, 100%. Number of buildings, 7,866. House area, 78%. Street area, 22%. Average slope of area, 1 in 60. Time of concentration, 18 minutes.

Minimum, maximum, and average results of 28 gaugings.

Date	Rainfall Inches Per Hr.	Sewer Flow				C
		C.	F.	P.	S. P. A.	
Feb. 4, 1904.....	0.198	0.246				124%
Sept. 13, 1904.....	0.326	0.110				34%
Average						83%

*5. C. E. Gregory—Trans. Am. Soc. C. E., Vol. LVIII, p. 458, June, 1907.

*10. Lloyd-Davies—Proc. Inst. of C. E., Vol. CLXIV, p. 41, et seq., 1905-1906.

(2) Charlotte Road Sewer:

Drainage area, 232 acres. Population per acre, 17.2. Number of buildings, 500. Street and road area, 10%. Estimated amount of imperviable area, 18%, increasing to 42% as the perviable area becomes saturated. Time of concentration, 12 minutes. Minimum, maximum, and average results of 21 gaugings:

Date	Rainfall Inches Per Hr.	Sewer Flow C. F. P. S. P. A.	C
Mar. 8, 1904.....	0.100	0.029	29%
Aug. 22, 1904.....	0.165	0.048	29%
May 21, 1904.....	0.198	0.030	15%
Aug. 17, 1904.....	0.338	0.051	15%
Average			22.4%

(3) Bordesley Street Sewer:

Drainage area, 19.32 acres. Population per acre, 147.0. Percentage of drainage area impervious, 100%. Number of buildings, 568. Street area, 25%. House area, 75%. Time of concentration, 6.5 minutes. Minimum, maximum, and average results of 8 gaugings:

Date	Rainfall Inches Per Hr.	Sewer Flow C. F. P. S. P. A.	C
Mar. 29, 1904.....	0.240	0.304	126%
Apr. 14, 1904.....	0.414	0.386	93%
Average			105%

These gaugings show that from small, totally impervious areas, the whole rainfall may run off as fast as it falls. From larger areas, also totally impervious, the run-off is smaller.

8. *Miscellaneous Data.* Mr. Alva F. Grover described some sewer gaugings made in Kansas City.*¹¹ The percentage of the total rainfall discharged by the sewer was measured and recorded, as given in Table XIX.

TABLE XIX.

TOTAL PROPORTION OF RAINFALL REACHING SEWER.

Gaugings by Grover.

Date, 1892	Duration of Storm Hr. Min.	Total Rainfall Inches	Per Cent of Total Rainfall Discharged
Aug. 23.....	2 25	0.77	16.0%
Sept. 8.....	2 35	0.13	12.0%
Sept. 27.....	2 55	0.32	60.6%
Oct. 13.....	1 55	0.18	4.7%
Oct. 17.....	. ..	0.40	10.7%
Oct. 31.....	. ..	0.65	11.1%

No explanation of the high run-off on September 27th is given.

Mr. Gregory notes a single gauging made at Hartford, Conn., by Mr. F. L. Ford. He states that the greatest lack in the gauging is for accurate knowledge of the characteristics of the watershed.

*11. A. J. Grover—Trans. Am. Soc. C. E., Vol. XXVIII, p. 1, Jan., 1893.

Three automatic rain gauges were adjacent to the tributary area. The results of the gauging follow:

1. Tributary area	280	acres
2. Percentage of impervious area.....	45.0	
3. Time of flow through longest line of sewer (minutes).....	17.0	
4. Equivalent uniform rate of rainfall (inches per hour).....	3.4	
5. Duration of this continuous rate of rainfall (minutes).....	17.0	
6. Observed value of <i>C</i> (per cent).....	10.0	

It is possible that the time of concentration should be increased to allow for the time of flow over the surface to the sewer. If the characteristics of the watershed are uncertain, the recorded proportion of impervious area may be excessive. Modification in both of these figures might explain the low value of *C*.

The foregoing data comprise most all that has been published. It is understood that gaugings are under way in St. Louis and Brooklyn, and it is hoped that the results of these gaugings will be published from time to time, so that the selection of the proper values of *C* may be done with greater certainty.

Gaugings have also been made in Philadelphia, Pa. The results can be found in the annual report of the Bureau of Surveys for 1911. It is hoped that these and other data will be arranged for presentation and discussion.

Four sewers have been gauged in the Sanitary District. These are the Robey Street Sewer, discharging into Bubbly Creek, the Diversey Boulevard Sewer, discharging into the North Branch; also the Davis Street Sewer in Evanston, and the Cherry Street Sewer in Winnetka, both discharging into Lake Michigan. Weirs were built at the outlets of all these sewers, and Bristol Water Level Recording Gauges were installed. The records secured at Winnetka and Evanston are the most reliable.

The Robey Street area lacks uniformity, and a description of the controlling conditions is difficult. The street grades are above the general ground surface, so that a great deal of the area does not discharge rainwater to the sewer, except as it percolates through the ground. The paved and sewered streets are scattered quite irregularly over the area, which is very long and narrow. No rain gauge is located on the area, but the gauges at Center Avenue and Western Avenue are on either side and only two miles apart, so that a fairly close approximation of the rainfall is possible.

The Diversey Boulevard area is more regular. Unfortunately, however, the nearest rain gauge is the Government gauge on the Post Office, 4.5 miles south, the next nearest being the gauge at Evanston, 8.25 miles north. The records derived from these two sewers can only be considered approximations, and would not be included, were it not for the comparative scarcity of such gaugings.

The conditions for securing accurate gaugings at Evanston and Winnetka are satisfactory. The records of the gaugings follow:

Winnetka Gaugings: In May, 1912, a rain gauge was placed

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on the village hall, in Winnetka, and in July, 1912, a sewer gauge was placed at the outlet of the Cherry Street Sewer. This sewer receives the house and storm sewage of the northeastern section of the village. The total tributary area is 381 acres. The rain gauge is located about 3500 ft. from the sewer outlet, in the southwest corner of the tributary area. The area is practically all residential. A careful study of the area indicates that the impervious area amounts to 10%. The population per acre is about 4.5. The area is rectangular, about one mile long and 0.6 mile wide, the Cherry Street outlet being at the extreme southeast corner. The time of concentration is, therefore, comparatively large. It is estimated that sixty minutes is required to make the whole area tributary. A short ridge about 30 ft. high cuts across the center of the area in a north and south direction; above and below the ridge the surface slope is about four per thousand. The outlet sewer is a 26 in. by 39 in. egg shaped brick sewer. Computations, based on the gaugings of seven storms, are given in Table XX. The drainage area is shown in Fig. 6.

Robey Street Gaugings: The Robey Street Sewer drains approximately 2513 acres of house and storm sewage. The population per acre (1911) is 15.5. The area is about 5.6 miles long and varies in width from 0.8 to 1.0 mile. About 7.6% of the area is impervious. The area is practically flat throughout, and most of the lots lie below the street grade. The outlet sewer is 9 ft. 0 in. brick circular section. The time of concentration for the whole area is estimated to be seven hours. Practically all of the impervious surface, however, is in an area tributary to the sewer outlet, within five hours. The area adjacent to the outlet contains very little impervious surface. The area which becomes tributary during ordinary storms lasting from two to four hours, therefore, contains most of the impervious surface, and this equals about 15% of the smaller area. The time of concentration was taken off the sewer gauge as being the time after the sewage surface first began to rise to the time of maximum discharge. The tributary area was then computed to correspond. No short storms have been included. The rainfall was taken from the records of the rain gauge at 31st Street and Western Avenue, about one mile away. The computations of the records are given in Table XXI.

Diversey Boulevard Gaugings: This area contains about 725 acres. Of this it is estimated that 22% is impervious during dry weather. The population per acre (1911) is 32.5. The district is about 2.4 miles long by 0.5 mile wide. The area is very flat and many of the lots lie below the street grade. The time of concentration for the whole area is estimated to be 75 minutes, and 580 acres are tributary in 60 minutes. The intensity of rainfall was proportioned by distance between the intensities recorded at Evanston and on the Chicago Weather Bureau gauge. The outlet is a 7 ft. 6 in. brick circular sewer. The records of two storms are given as follows:

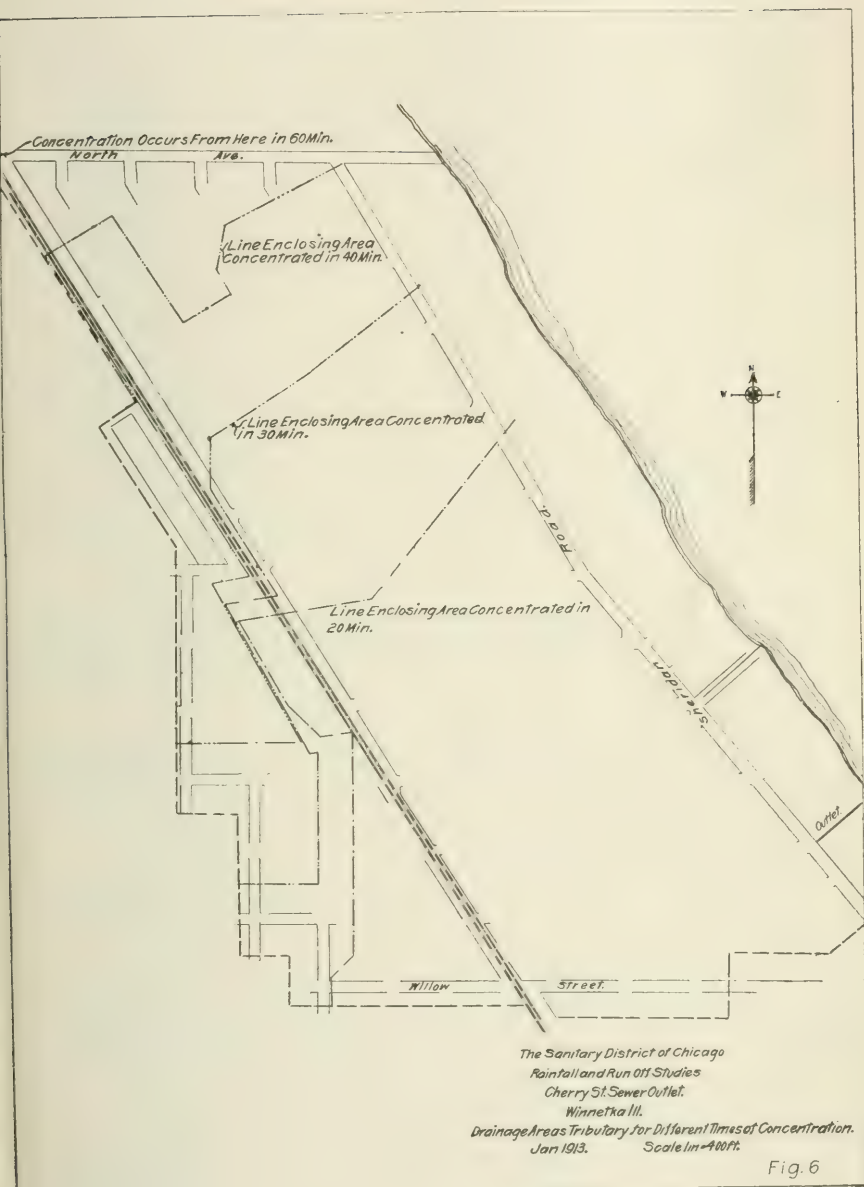


Fig. 6

TABLE XX.
Winnelka Gaugings—Cherry Street Sewer Values of C.

Date, 1912	Time Before Maximum Discharge Minutes	Area Tributary in This Time Acres	Average Rainfall This Time Inches per Hour	Rainfall During This Time Cubic Feet per Second.	Maximum Flow in Sewer in Excess of Weather Flow	C	Remarks
July 20.....	75	381	0.163	62.1	13.5	21.7	Sudden moderate shower 12 hours after previous storm
July 20.....	50	320	0.200	64.0	15.0	23.4	Short, sharp shower
July 23.....	25	160	0.450	73.9	15.5	20.9	Second of two showers
July 28.....	60	365	0.154	56.2	12.3	21.8	Short, quick storm
July 28.....	30	195	0.390	76.8	11.7	15.2	8 hours after previous storm
Aug. 8.....	75	381	0.22	82.3	13.0	15.8	Sharp, short shower
Aug. 9.....	20	130	0.90	116.8	20.2	17.3	

TABLE XXI.
Robey Street Gaugings—Values of C.

Date, 1912	Time Before Maximum Discharge Minutes	Area Tributary in This Time Acres	Average Rainfall This Time Inches per Hour	Rainfall During This Time Cubic Feet per Second.	Maximum Flow in Sewer in Excess of Weather Flow	C	Remarks
Sept. 21.....	120	580	0.130	75.4	5.0	6.6	First part of storm
Sept. 28.....	120	580	0.070	40.6	6.0	14.7	Latter part of storm
Sept. 2.....	180	900	0.033	29.7	5.0	16.8	Last part of long storm
Oct. 2.....	120	580	0.060	34.8	3.5	10.0	First part of light rain
Oct. 8.....	195	990	0.111	109.9	18.0	16.3	Last shower in six-hour storm
Oct. 22.....	210	1080	0.034	36.7	4.7	12.8	Long, light rain
Oct. 30.....	240	1290	0.052	67.0	18.0	26.8	Last shower of a ten-hour storm

1. October 11, 1912,—short storm, no previous rain. Evans-ton gauge recorded 0.34 in. in an hour and the U. S. Gauge 0.31 in. Assuming a rainfall of 0.32 in. over the Diversey Boulevard area, the value of C is estimated to be 22.7%.

2. October 31, 1912,—long storm, ground previously soaked. Both gauges showed 0.05 in. per hour rainfall. At this rate the whole area was contributing to the sewer. The estimated run-off is 67.7%. These two rainfalls were not severe and were quite uniform over a large area.

SUMMARY.

A brief summary of the measured values of C is given below.

(a) For suburban residential districts, with average slopes and populations of about 5 to 10 per acre, C may have a value of 20 to 25%.

(b) For urban residential districts with flat slopes and populations up to 35 per acre, the value of C will range from 25 to 40%.

In hilly localities where the lot areas become saturated and the run-off can reach the sewer, this value of C may be as high as 70%.

(c) For thickly built-up urban districts, the value of C will vary from 60 to 100%.

These values are, of course, approximate only. It is believed that for each particular design, a better choice can be made by close reference to the original records of the gaugings or the summaries presented herein.

CONCLUSION.

This paper has been prepared chiefly for a discussion, and is not, therefore, as complete as it might be. Only general indications of values are intended. It is hoped that the paper will suggest lines along which further data will be presented in such shape as to bear, with some degree of uniformity, upon the rainfall and run-off problem. The Sanitary District data are not as yet complete.

It is hoped that the discussion will bring out suggestions for further gaugings.

With regard to the standard formulae, it would seem that they are particularly useful in large sewerage districts in which the results in practice of the application of a formula are known, and the sewerage department has become used to expressing their judgment through the formula. They are dangerous in that they can be used without thought, and they do not adapt themselves so well to refinements in the design. The storm sewerage of a town or city is the most costly part of the system. Careful design may effect a considerable saving. A rule-of-thumb method, or the application of a formula without judgment, should be no longer necessary.

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DISCUSSION OF PAPERS BY MESSRS. THON, HOWSON, AND GREELEY.

Langdon Pearse, M. W. S. E. (Chairman): You have heard the papers. Discussion is now in order. I hope some of those present have come prepared to add something to the material presented in these two papers. They are of a great deal of interest to all engineers in hydraulic practice, and the general elements are common in most of the problems we have outlined, particularly the matter of reservoir design and the caring for storm run-outs either from reservoirs or in sewer work.

C. B. Burdick, M. W. S. E.: Inasmuch as I had some connection with the preparation of the data given in the paper upon the Kentucky watershed, it may not be out of place for me to say something in regard to how these data were worked up and why.

Until one has attempted to analyze a 25 year record of daily reservoir stages and rainfall he will hardly appreciate the amount of labor involved; and, as might be expected, the consideration of such records is usually a part of the design of some work involving comparatively large expenditures. This particular record was worked up for the following reason: The Lexington Water Company has developed now up to the full supplying capacity of the No. 1 watershed, as described in the paper, and they are face to face with the necessity of making a material additional expenditure for increasing their supply. It might be thought that with their long experience upon the present watershed they would have a good idea of what could be done upon this next adjoining watershed. But the problem needed to be solved with comparative accuracy because the investment involved the addition of from 15% to 20% of the total investment in water supply; as it would add nothing to the gross return from the sale of water except in the future, it was important to make this expenditure reasonable in amount, and, if possible, find a way to develop the watershed progressively, distributing this large expenditure over a period of time and depending upon future revenue returns. It was desired to secure the water needed at the least unit cost considering capital charges as well as depreciations and operating expenses. From the records of water in the past, records of the pumpage, and the growth of the population, it was practicable to estimate quite accurately the requirements of the future, and with these data in hand it was estimated that an expenditure of, I believe, not to exceed one-third of the total sum in the development of a dam and the purchase of land would provide for about 15 to 18 years in the future, deferring the expenditure of the remaining two-thirds to a later date. By reason of this investigation, the water company was able to make a large saving in the fixed charges on investments that probably would have been wise to secure if the investigation had not been made.

It is worthy of note that an investment has already been made on that No. 4 watershed. There is a small dam about 12 or 14 ft. high already built and some water has been collected in the past

three or four years by means of that dam and pumped over into the reservoirs on the No. 1 watershed. These investigations clearly indicate that the investment would not have been productive of any water at all in the driest season on record; that the reservoir was of such a depth it would have been practically dried up by evaporation even if no water at all had been drawn from it. We investigated that matter somewhat in order to ascertain if it would not be possible to build a low dam, slightly higher than the one they have at present, that would impound some water and confine the flowage to land already owned by the water company. This investigation indicated that a dam two or three feet higher than the present one would have gone dry during the driest period of the record, even if no water had been drawn from it for use in the supply. Exhibit No. 10 does not show the fact that I brought out last, in that the curved lines illustrating the Hickman Creek yield are not carried sufficiently far to the left to show the intersection with the line of zero yield. The line would intersect the zero yield at about 12,000,000 gallons storage. You will notice the rather striking difference in the curve for the Sudbury watershed, in which a yield of 100,000 gallons per square mile per day would have been possible with no storage at all. It is the difference between a stream that goes entirely dry and one that has a constant flow.

John F. Hayford, M. W. S. E.: In connection with the last remark of the previous speaker, is there not a mistake in Exhibit No. 10, where it is said that the minimum flow of the Croton watershed is zero?

Mr. Burdick: I did not prepare the diagram so I do not know. The author can doubtless elucidate that point.

Mr. Howson: Referring to the minimum yield of the Croton and Sudbury watersheds with no storage, the figures at the top of Exhibit No. 10 are correct. The data were taken partly from Fig. 48, Freeman's Report on New York's Water Supply. A study of this diagram shows that the Sudbury watershed will yield 100,000 gallons per day (the equivalent of 2.15 in. on the watershed per year), with no storage, while the Croton with no storage has no yield.

It would seem that the Croton, having the larger watershed, would have the more constant flow and the larger minimum flow, but the records do not show this to be the case. The Sudbury watershed probably receives a considerable amount of water for its flow from the sands and gravels of the glacial drift which impound the water and release it slowly during periods of low flow.

Mr. Burdick: In connection with the Kentucky project, the question of spillways came up on that reservoir. Shortly before the investigation was made there, a large flood was observed on the watershed. I do not now remember the figures, but probably Mr. Howson can tell us what they are.

Mr. Howson: The maximum flood which was recorded figured, I believe, about 160 cu. ft. per sec. per square mile. That would be equivalent to something over 0.2 per acre. The dam had only been built ten years and there is only one really heavy flood observation.

C. C. Saner, ASSOC. W. S. E.: Was that on country territory?

Mr. Howson: Yes, it was on country territory. Rock lies close to the surface there and drainage returns quickly.

C. B. Lewis, ASSOC. W. S. E.: It may be a matter of general interest, not directly connected with this paper, to explain a few conditions, operating conditions, of the Indianapolis waterworks, with which I was connected four or five years ago. They have next to no natural storage there and have built a 5,000,000 gallon artificial reservoir.

The accompanying illustration shows the condition and the operation. A dam is located on White River at Broad Ripple, about eight miles above the city of Indianapolis. A canal follows the river from the dam to West Washington Street, where it flows into the river, and where Pumping Station No. 2 has been developed. Pumping Station No. 1 is at Riverside, not far away. Near the latter station is a filter plant where there is a small amount of storage. The water comes through the filter plant and flows to a suction well at Riverside. There is also a 5,000,000 gallon reservoir at Riverside that feeds into the suction well. The suction well feeds the pumps also and there is a line down to West Washington Street, so that this is a sort of general equalizer. The pit is a very small one, holding only a few hundred thousand gallons. Water is forced by direct pressure from these two pumping stations through inter-lacing series of mains to all sections of the city. The interesting point is that the water which comes down from this canal is filtered and goes to the pumping station and also goes to West Washington station and operates the turbine, so that if the filter is robbed for the turbine plant there is not a sufficient amount at the water wheels, and vice versa. As it is a direct pressure system, there is no possibility of equalizing on the pumps.

At the time I was there the average daily pumpage for the whole year was about 17,000,000 gallons per day; there was a period of an hour or two when the pumpage was at the rate of 42,000,000 gallons and the pumps had to take care of the fluctuation. That was about five years ago, however, and I do not know what is the present average daily pumpage.

An additional supply is developed by a series of thirty deep wells, which vary in yield from the worst of them yielding nothing to the best of them yielding about 400,000 gallons per day. They are worked by the air lift system and the operating problem that we faced was to see if, by juggling the small storage that we had at the filter plant with the 5,000,000 gallons storage, we could run the compressors that operated the air lifts at a uniform rate, because.

otherwise, it made a great deal of difference in the boiler room efficiency. We used every method we could think of in working on this problem, and the only conclusion we reached was that it could not be done. We improved conditions somewhat so that there were only about three to four hours a day when we had to drive the compressors to their maximum and blow more air than water, but 5,000,000 gallons capacity of storage was about all we could develop.

The general point I am trying to bring out is to show the effect

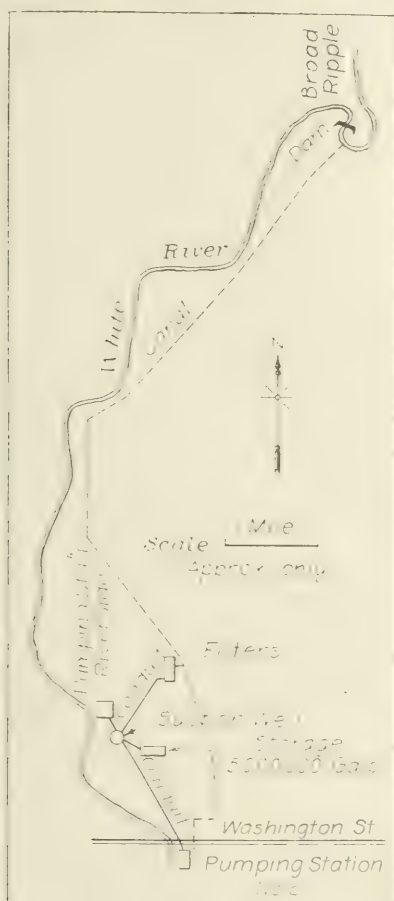


Fig. 7.

of storage on the difference between maximum and average, and how a comparatively small amount of storage will sometimes affect operating efficiency to a high degree.

A Member: What was the population of Indianapolis?

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Mr. Lewis: At that time it was close to 200,000—between 150,000 and 200,000. But there is a modifying influence at Indianapolis which is the fact that there are a great many private wells. A packing company, I believe, operates its own private deep well supply. Several of the large hotels, breweries, and office buildings have their own private water supply, because of some fancied superiority of quality, or because they can get it cheaper than the water company can give it to them, or because they happened to have had it before the water company went into operation. All over that part of the country one can easily put down a well and get water which is good except for its hardness. It is a very poor water, however, for boiler use.

L. K. Sherman, M. W. S. E.: I wish to commend these two carefully-prepared papers and the valuable data they contain.

Several years ago I compared the rainfall and the run-off of a certain drainage area of about 1,000 square miles. We had the very best facilities for comparison. There were six Government rain gauges in this area, and we had a daily record of the stream flow as reported by the Government observation station. Realizing this valuable information, I decided to work it up and make a careful comparison day by day of the rainfall with the actual run-off. I started off and plotted this up, and as I went along and secured my results I began to be very much disappointed. I had anticipated that here were the data for a valuable record, but the results were erratic and there was apparently no logical ratio between the rainfall and the daily run-off. In fact, I became quite peevish over it and threw the stuff into the waste-basket. After that, I was inclined to oppose, not to say "knock" these various attempts to make formulae based almost entirely on rainfall, which are very nice from a theoretical standpoint but which do not give the true results. I think Mr. Greeley hit the nail on the head when he said the only accurate way to determine the run-off from a sewered area is to measure it.

Early in 1912 I started a campaign for measuring the run-off from sewered areas, by presenting a short paper before this Society* on that subject, and I believe the discussion has led to results. I take considerable credit to myself tonight for the valuable data that have been collected by these gentlemen during the past year in and about Chicago.

J. H. Warder, M. W. S. E.: What was the trouble with those records that you attempted to tabulate, and which you got tired of and threw in the waste-paper basket?

Mr. Sherman: They showed no consistent relation whatsoever, amongst themselves. One day there would be a tremendous down-pour and that would be followed by a perfectly reasonable run-off. A day or two later the same condition would be repeated and there was no run-off whatsoever or a very trifling one. A third day there would be a rainfall not nearly as great as this first day I spoke of,

*Journal, April, 1912, Vol. XVII, No. 4.

and the run-off would be three times as big as what occurred on that day. The results were absolutely erratic and unscientific, and were affected not only by the particular character of the soil, but also the condition of the soil. One day the soil might be saturated; another day it would be dry. I do not question the data; they were as perfect as could be obtained, but it is not safe to state what the percentage of run-off will be without knowing a great many conditions. So I have come to the conclusion that the run-off is influenced not simply by the rainfall but by many other factors, the rainfall being but one of them. It seems to me that the only scientific way to get at this question of the relation between rainfall and run-off is in a manner similar to that indicated by the authors of these papers. In this way I believe one can get comparisons that will show some definite percentage. It might be 20% in one year, but it would not show any fixed percentage when individual down-pours were compared even on the same drainage area.

When I was in court one time, a lawyer asked me, "What is the average annual rainfall?"

I said, "Thirty inches."

"Well," he said, "suppose I were to show you that there had been an annual rainfall of sixty inches; now, then, how would you change your run-off, the size of your drainage ditch in that event?"

I told him I would pay no attention to it.

He asked, "Why?"

I said, "Simply because we have the measured maximum run-off and after we have that we do not care what the rainfall is."

Mr. Burdick: I think, without question, the rainfall must be considered. It is wise to consider it in any sewer run-off formula, although, when we are considering the drainage of cities in the temperate zone of North America, the variation in the rainfall intensity would probably be found not great, if we had records sufficiently long to demonstrate what are the prevailing conditions in the several localities. In the temperate zone, even though the annual rainfall and the distribution of rainfall will be somewhat different at the various places, in the design of a sewer system what we are striving for is the maximum run-off which is produced by single storms. It would be instructive to see the rainfall rate tables for the various localities platted upon one diagram in order to bring out the difference. Perhaps Mr. Greeley can give us some information on this point in view of his recent study of the records.

Mr. Greeley: I can give no definite information, but there are two thoughts that come into my mind. The preparation of the tables as presented in my paper gives one an opportunity to pick out the probable frequency of intense storms. I think perhaps that might vary more than the actual maximum intensity of different sections.

I wrote Mr. Fuertes, of New York, asking him for some data relative to rainfall in Harrisburg. He replied that geographical

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conditions in each location made a great difference; that Harrisburg, on account of certain geographical conditions (he did not state what they were), did not have a typical rainfall intensity curve.

Mr. Burdick: That might be influenced, perhaps, by mountains or something of that kind.

Mr. Greeley: Yes; for instance, out about Puget Sound the rainfall may vary from 70 in. to 10 in. per year on the two sides of the Olympic range of mountains.

Mr. Burdick: To a certain extent the frequency of these down-pours is significant; but, after all, we must build our sewers to take most of the storms in all cases within a reasonable length of time, and after a certain frequency, additional frequency does not cut much figure in the design of a sewer system.

Mr. Saner: The accompanying table records a few of the gaugings taken on the Davis Street sewer at Evanston, showing a variation in ratios of 7 to 22. The last column gives the per cent of rainfall that passed through the sewer, and it will be noticed that the highest is 20.3% for a severe storm lasting one hour and thirty minutes.

Date.	Time of Concentration.	Time of Max. Disc.	Av. rate of rainfall in inches per hr. during per. of con'n	Area.	Av. Rainfall C. F. P. S.	Flow in Sewer.				
						Maximum Flow Following Period of Concentration.	Average Dry Weather Flow.	Storm Water Run Off.	Ratio of Storm Flow to Rainfall.	Total Proportion of Rainfall Reaching Sewer.
6-4-12	15 M.	1 H. 30 M.	.60	141	84.6	13.3	1.5	11.8	13.9	14.2%
7-13-12	10 M.	1 H. 30 M.	2.10	100	210.	29.0	2.0	27.0	12.8	20.3%
7-21-12	45 M.	5 H.	.15	420	63.	12.0	2.0	10.0	15.9	7.3%
5-28-12	45 M.	3 H. 30 M.	.32	420	134.	32.0	2.0	30.0	22.3	8.5%
8-20-12	10 M.	1 H. 30 M.	.78	100	78.	7.6	2.0	5.6	7.2	6.18%

The district drained by the Davis Street sewer (an area of 420 acres), is all built up and paved. I have estimated that 20% of the area is impervious. Although the streets have fairly flat grades, the drainage, as compared with Chicago, is very good. The grades of the sewers are irregular, flat grades being followed by steep ones, and with such grades it is not clear just why such peculiar diagrams have been obtained. Sharp storms seem to get to the outlet all at once, although the remote part of the district is 40 minutes from the outlet. The gauge at the outlet would go up 25 in. and then down almost as quickly. I submit the table of five storms.

The weir at the outfall was made of steel with contracted ends. A manhole was built 10 ft. up-stream, and over it a house was placed, containing a Bristol Water Level Gauge. A tipping bucket rain gauge was placed at one corner of the district with a good exposure. Some difficulty was experienced with rags and paper carried by the sewage, and it was found that a better plan would have been

to have constructed the manhole to the side of the sewer and connected it by a small pipe to the sewer.

During the past year I noticed a sewer run-off curve which gave the depth of the water at the outlet about 0.3 of the depth back a few hundred feet.

There was a severe rainstorm in October, 1912. It rained for three days and the path of low barometric pressure passed directly over Evanston. The hardest rain came the evening of October 11th, and amounted to $1\frac{1}{4}$ in. in 20 minutes. Many of the streets were under water from curb to curb.

The Davis Street sewer was running under a head at the mouth, and if our gauge had been working then, it probably would have been broken. I took off some of the manhole covers in that system 15 or 20 minutes after the rain, and water was standing within 3 or 4 ft. of the top. Flooding of sewers extended as far south as Lawrence Avenue. The Winnetka gauge did not show as severe a rainfall as Evanston, and there was very little rain in Chicago that evening.

I figured that the run-off was 0.2 c. f. s. per acre, and have been informed by the Weather Bureau that this is very close to the high record of storms.

Professor Hayford: When Mr. Saner spoke of 1.2 in. in 20 minutes as being a big rainfall, I mentally compared that with a record-breaker rainfall in the Canal Zone, which was 2.4 in. in 3 minutes! As this was reported on two automatic gauges, the two operating at the same point, it was thought there could be no mistake. I happened to see a rainfall in Panama City of 7 in. in less than three hours. Many of the tropical rainfalls, however, are comparatively easy rainfalls, coming early and often.

A Member: What kind of rain gauges do they use?

Professor Hayford: I cannot answer the question categorically. One of the two gauges was the bucket type,—deep bucket form,—and the remark was made in connection with this case that they must have been having a fever to keep up.

Mr. Lewis: There are two considerations that present themselves to me in connection with these sewer run-offs which may somewhat account for the erratic records of relation of run-off to rainfall. One of them is the hour of the day and the day of the week when the rainfalls occurred. These sewers were most, if not all, as I understand it, combined sewers. I should think, without having the figures, that if a heavy rainstorm came at a particular time—on Monday, for instance, when many dozen wash tubs are being emptied,—it might have a marked influence.

Another consideration is, with the network of sewers having slight gradients, in a city of the type of Chicago, a rainfall covering only part of the area coming south as far as Lawrence Avenue, as was mentioned, might back up quite a little distance into tributary sewers that were not receiving any rainfall directly, and thus pro-

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duce a storage capacity which would be very difficult to account for in any mathematical way.

Mr. Sauer: The difference between the night flow and the day flow in the Evanston sewer, I think, was about 1 in. or $1\frac{1}{2}$ in. over the weir. That curve is very consistent. It started at half past five in the morning and got to the maximum, on dry-weather days, at about eight o'clock. The gauge was very accurate. The Y. M. C. A. empty their swimming tank on Saturday night, and, not knowing that they had a tank, it was a long time before I found out what was the cause of the hump on my curve which measured 72,000 gallons on Saturday nights. Later I ascertained that the capacity of the Y. M. C. A. tank was 75,000 gallons, and I then knew that the hump on the curve was due to that tank. I think that is a very good check on the accuracy of the gauge. I have measured, several times, the discharge for 24 hours and we have estimated the population there at 5,000, and figuring the water supply it checks very closely with the water supply of the district.

Mr. Lewis: I would ask if anyone recollects approximately the figures published in the engineering press recently of a very heavy rainfall in the Philippines?

Mr. Warder: In a talk before this Society, Mr. E. L. Lundgren, formerly of the Bureau of Public Works of the Philippine Government, mentioned a very heavy rainfall there last year, lasting four days, when the total rainfall was 88 in.

W. W. Horner (Principal Assistant Engineer, St. Louis Sewer Department):

The St. Louis gaugings having been mentioned in Mr. Greeley's paper, the writer believes that a brief progress report on them may be of interest.

This work is confined to the Clarendon sewer district, a typical residence section of the West End. In the main sewer of this district, nine Bristol Water Level Gauges have been installed. The instrument farthest up-stream gauges an area of 126 acres, and the lowest 713 acres. An additional gauge is placed in a small lateral draining 31 acres. The permeable area is between 50% and 60% for different portions.

Three tipping bucket rain gauges have been placed in the area. These have been found necessary on account of the large local variation in intensity of the heavy showers. [In this connection, the records of eight automatic gauges and five standard gauges within the city limits are being compiled in an attempt to determine the extent of area covered by rains of different intensities and the average direction and velocities of the storms.]

Over thirty heavy rains have been measured at from one to ten of the stations each, so that we have now probably 200 different records. These are primarily continuous, automatic records of the water stage at the different points. From the various maximum stages, the discharge has been computed by Kutter's formula, using,

originally, the flow line grade of the sewer. With the increased number of gauges in service, however, it has been noted that there are marked differences between the grade of the sewer and the water surface grade. For example, in a 9 ft. sewer for one rain a depth of flow, at one point, of $4\frac{1}{2}$ ft. was observed; 1,000 ft. down-stream the depth was less than 4 ft. though several tributaries entered between, while 500 ft. farther down-stream, the depth was over 5 ft. Similar variations have been noted in other rains. The sewer is uniform as to grade, size, and condition. The most reasonable explanation of these differences is that the flow at the upper and lower gauges is disturbed, in the case of the upper gauge, by a curve 200 ft. up-stream, and of the lower by a 3 ft. lateral, discharging into the main sewer, nearly at right angles, 100 ft. above the gauge. In both cases the velocities would be materially reduced from that computed by Kutter's formula. In another case, a sharp reverse curve and small local obstruction has been found to create a back pressure above of over 10 ft., although the sewer below was only slightly overcharged. Where the sewers were overcharged, the discharge has been computed on the hydraulic gradients and is probably quite accurate. For partial flows, however, it has been decided that actual velocity measurements are necessary to secure accurate results. We are now preparing to install automatic current meters in connection with one of the water level gauges, and, by varying the position of these in the section, to determine finally the mean velocities for all stages of flow in the sewer. From these velocities, the discharge on all former gaugings can be computed. Another year will probably be required to secure all necessary data. The results of this work so far have shown the necessity for careful detailing of the connections between laterals and mains so that the velocity in both main and lateral will be decreased as little as possible. Sharp curves or abrupt change in alignment must also be avoided unless compensated in grade, if the velocities and consequent capacities are not to be reduced below the computed values.

There seems to be some confusion in the meaning of the terms "percentage of run-off" or C . It has sometimes been taken as the ratio of maximum run-off to the average rain rate from the beginning of the rain, but more generally to the average rate during the critical time t . Gregory's suggestion of introducing the time of flow to the inlets is much better. In this way the maximum discharge is compared to the average rate of rainfall from a time ($i_1 + t$) before the maximum discharge to a time (i_2) before the maximum discharge, i_1 and i_2 being the inlet time at the extreme and nearly inlets respectively. In this case, the time considered would be nearly t minutes, but set back about i minutes before the occurrence of the maximum discharge.

In the St. Louis work, a still further refinement has been introduced as an alternative. The areas above the point of gauging are divided into sections. The run-off from the first section (a_1) will reach the gauge within five minutes after entering the sewer;

from the second (a_2) in from five to ten minutes after entering the sewer, etc. Suppose the time of flow through the sewer to be 30 minutes, there will then be six sections of area, the flow of each requiring five minutes longer to reach the gauge than that from the next section below. If the average inlet time is five minutes, at the end of 35 minutes the whole area will be contributing run-off at the gauge. If the run-off were 100% in each section of area, it would equal $a_6I_1 + a_5I_2 + a_4I_3 + a_3I_4 + a_2I_5 + a_1I_6$, where I_1, I_2 , etc., are rates per hour for each five minutes from the beginning of the rain. The 100% run-off for the next five minutes would be $a_6I_2 + a_5I_3 + a_4I_4 + a_3I_5 + a_2I_6 + a_1I_7$, etc., through the rain. Also if one rain gauge is located in a_1 and another in a_6 , the intensities used may be taken from the nearest gauge or may be averages of both, thus applying to each section of area as nearly as possible the rate of precipitation falling on it at a particular time.

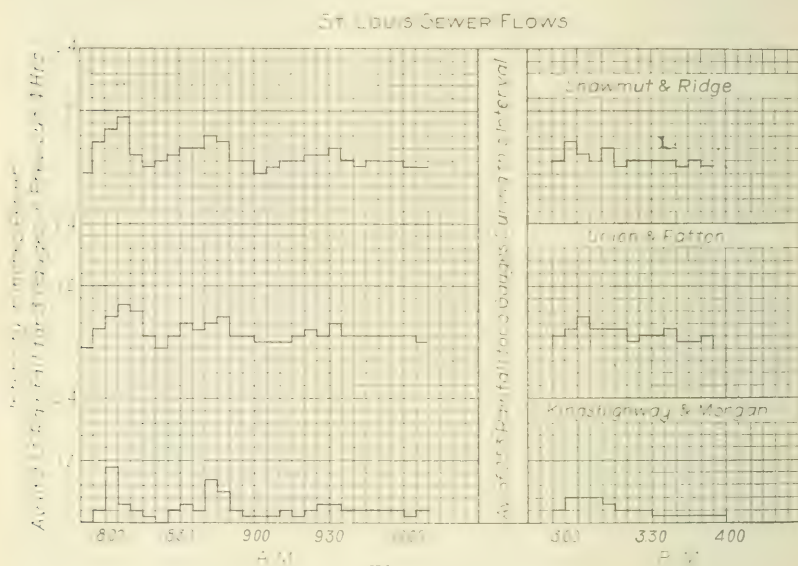


Fig. 8.

In the graph given herewith, the records of the three rain gauges are shown separately. On the other plat are three "curves." The step curve is the "100% run-off" line as described above; the dash curve is the average rate for a time t multiplied by the whole tributary area; the heavy full line curve is the discharge computed by Kutter's formula from the observed stages of water. The time difference between the maximum of the step curve and discharge curve is an indication of the average inlet time plus some "lag" due to storage. The ratio of maximum discharge to the maximum of the 100% run-off curve is very closely a true percentage of run-

off; the ratio to the maximum of the dash curve is the common value of C . It is the intention to work out both factors for all the gaugings,—the latter for use in district sewer design, where changing local conditions and the use of stock sizes of sewer make refinement unnecessary, and the former for use in more important projects especially of reconstruction and relief where the details of run-off are subject to accurate computation.

Another phase of this work which has just been started is the study of run-off from the unit areas, that is, the areas draining to individual inlets. Two special cases have been taken for the work, one an area consisting principally of back yards and alley in which

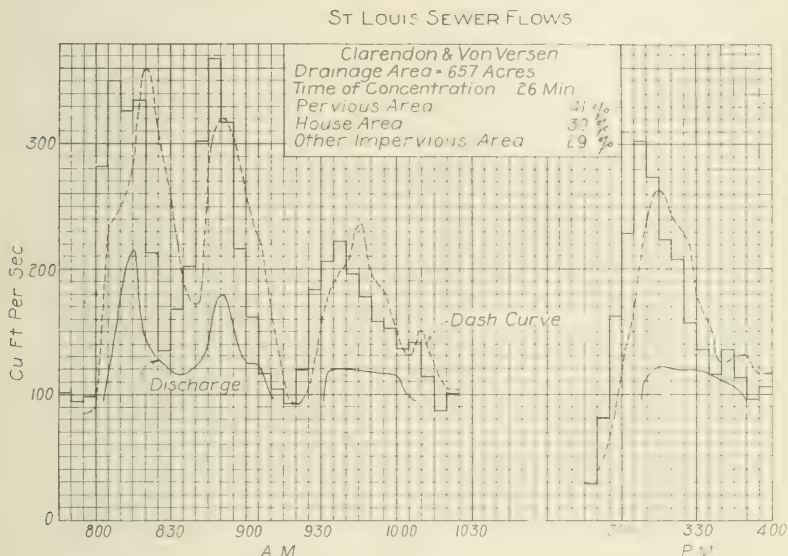


Fig. 9.

the slope is slight; the other a whole block closely built and having steep grades. The inlets have been reconstructed, and a chamber containing a "V" notch weir built under the street between inlet and sewer. Bristol gauges are installed to measure head on the weirs. All adjacent inlets have been enlarged and arranged so that no water can cross over from one inlet area to another, even in the heaviest rains; the exact extent and character of the inlet areas have been plotted. The values of the run-off factor from these small areas will be of great service in analyzing the results from gauges in the sewer.

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Regular Meeting, September 8, 1913.

A regular meeting of the Society (No. 831) was held Monday evening, September 8, 1913. The meeting was called to order about 8:15 p. m., President Reichmann presiding, with about 175 members and guests in attendance.

The Secretary reported from the Board of Direction that at their meeting held Monday, June 30, the following had applied for admission into the Society:

Lewis Merril Markham, Las Animas, Colo.
Charles S. Head, Gary, Ind.
Edward Hughes, Gary, Ind.
Willard L. Houskeeper, Chicago.
Ansel Morris Burton, Gary, Ind.
Leon Kirsch, Chicago.
Ralph Alfred Goodell, Gary, Ind.
Jakob Natvig Matzow, Gary, Ind.
Harley George Overholt, Chicago.
Howard Randolph Perrin, Pawtucket, R. I.
Louis Forman, Valparaiso, Ind.
Joseph Russell Fox, Gary, Ind.
Carl August Sundstrom, Chicago.
Harold F. Doerr, Chicago.
Harry G. Raschbacher, Ann Arbor, Mich.
Andrew P. Ludberg, Gary, Ind.
Earl Hayhurst Casper, Chicago.
Roy S. Chase, Chicago.
Horace Norman Jones, Jr., Gary, Ind.
Ernst Leopold Pflanz, Gary, Ind.
Gottlieb Filippi, Chicago.
Alexis Wm. Farley, Chicago.
Charles Henry Fork, Gary, Ind.
Robert E. Godfrey, Gary, Ind.
Jacob W. Graver, Gary, Ind.
Stanley Jashemski, Gary, Ind.
Walter Sigfred Pedersen, Gary, Ind.
John Strom, Indiana Harbor, Ind.
Manuel A. Viquez, Gary, Ind.
Joseph Cleveland Wiggins, Gary, Ind.
Adelbert Diefendorf, Gary, Ind.
Henry Frank Dischinger, Gary, Ind.
Gerard Cornelius Dooge, Gary, Ind.
Glen Herbert Huntington, Gary, Ind.
Isaak March, Chicago.
Gustave C. Olsen, Gary, Ind.
Frank Vincent Owens, Chicago.
Manley L. Pulleyn, Valparaiso, Ind.
William Remmers, Jr., Chicago.
George Atwell Scott, Gary, Ind.
Ellsworth H. Strang, Gary, Ind.
George Weigel, Gary, Ind.
James Benton Schaub, Valparaiso, Ind.
John J. Kehoe, Chicago.
W. Lynn McGinnis, Gary, Ind.
Graham Ruchti, Chicago.
Alexander Louis Scholz, Chicago.
A. Frederick Zick, Chicago.

Samuel Arthur Krell, Chicago.
 Frank Eugene Vey, Chicago.
 Abbott L. Hayden, Chicago.
 Christ Jacobsen, Chicago.
 Walter H. Kien, Chicago.

Also that the following had been elected into the Society:

L. C. Blackwell, Gary, Ind.....	Associate	Member
Fred Lamotte, Valparaiso, Ind.....	Student	Member
Fred Ruchti, Gary, Ind.....		Member
Arthur C. Loud, Gary, Ind.....	Associate	Member
H. D. Oberdorfer, Urbana, Ill.....	Associate	Member
Charles Hahn, Gary, Ind.....	Junior	Member
George B. Hoke, Gary, Ind.....		Member
George W. Sommerfeld, Gary, Ind.....	Junior	Member
Edwin B. Styles, Chicago.....	Junior	Member
Ole M. Bolme, Gary, Ind.....	Associate	Member
Clarence J. Kennedy, Gary, Ind.....	Associate	Member
E. P. Benjamin, Chicago.....	Junior	Member
John C. Warkley, Gary, Ind.....	Junior	Member
Pierre Herber, Chicago.....	Junior	Member
J. Lester Corliss, Chicago.....	Junior	Member

That at the meeting of the Board of Direction, held August 4th, the applications of the following for admission into the Society were presented:

Alvin T. Eunson, Chicago.
 Paul Shields Bailey, Gary, Ind.
 J. Emil Bergquist, Gary, Ind.
 James Robert Patrick Kettle, Gary, Ind.
 Leonard Mauel, Chicago.
 Erwin M. Lurie, Chicago.
 Jesse Royse Grube, Valparaiso, Ind.
 Henry Bertram Watters, Wyoming, Ohio.
 Horace B. Horton, Chicago.
 Mathew Elbridge Dunlap, Urbana, Ill.
 Max Brown Higgins, Champaign, Ill.
 Arthur Lathrup Sawyer, Gary, Ind.
 Ernest E. Tupes, Gary, Ind.
 William Ray Hoback, Sherwood, Tenn.
 Paul H. Lazenby, Chicago.
 William H. Sallwasser, Chicago.
 Arthur Mitchell Duff, Gary, Ind.
 Walter Wilkinson, Gary, Ind.
 Harvey Martin Hansen, Chicago.

Also, that the following had been elected into membership:

Lewis M. Markham, Las Animas, Colo.....	Member
Charles S. Head, Gary, Ind.....	Associate Member
Edward Hughes, Gary, Ind.....	Junior Member
Willard L. Houskeeper, Chicago.....	Associate Member
A. Morris Burton, Gary, Ind.....	Associate Member
Leon Kirsch, Chicago.....	Associate Member
Ralph A. Goodell, Gary, Ind.....	Junior Member
Jakob N. Matzow, Gary, Ind.....	Junior Member
Harley G. Overholt, Chicago.....	Associate Member
Howard R. Perrin, Pawtucket, R. I.....	Student Member
Louis Forman, Valparaiso, Ind.....	Student Member
Joseph Russell Fox, Gary, Ind.....	Junior Member
Carl A. Sundstrom, Chicago.....	Member
Harold F. Doerr, Chicago.....	Junior Member
Harry G. Raschbacher, Ann Arbor, Mich.....	Member

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Andrew P. Ludberg, Gary, Ind.....	Junior Member
Earl H. Casper, Chicago.....	Member
Roy S. Chase, Chicago.....	Member
Horace N. Jones, Jr., Gary, Ind.....	Associate Member
Ernst L. Pfanz, Gary, Ind.....	Junior Member
Gottlieb Filippi, Chicago.....	Associate Member
Alexis Wm. Farley, Gary, Ind.....	Associate Member
Charles Henry Fork, Gary, Ind.....	Associate Member
Robert E. Godfrey, Gary, Ind.....	Associate Member
Jacob W. Graver, Gary, Ind.....	Junior Member
Stanley Jashemski, Gary, Ind.....	Associate Member
Walter S. Pedersen, Gary, Ind.....	Junior Member
John Strom, Indiana Harbor, Ind.....	Associate Member
Manuel A. Viquez, Gary, Ind.....	Junior Member
Joseph C. Wiggins, Gary, Ind.....	Associate Member
Adelbert Diefendorf, Gary, Ind.....	Junior Member
Henry F. Dischinger, Gary, Ind.....	Junior Member
Gerard C. Dooge, Gary, Ind.....	Member
Glen H. Huntington, Gary, Ind.....	Junior Member
Isaak March, Chicago.....	Junior Member
Gustave C. Olsen, Gary, Ind.....	Junior Member
Frank Vincent Owens, Chicago.....	Junior Member
Manley L. Pulley, Valparaiso, Ind.....	Junior Member
William Remmers, Jr., Chicago.....	Junior Member
George Atwell Scott, Gary, Ind.....	Junior Member
James B. Schaub, Valparaiso, Ind.....	Student Member
John J. Kehoe, Chicago.....	Junior Member
W. Lynn McGinnis, Gary, Ind.....	Junior Member
Graham Ruchti, Chicago.....	Junior Member
Alexander L. Scholz, Chicago.....	Junior Member
A. Frederick Zick, Chicago.....	Member
Samuel A. Krell, Chicago.....	Associate Member
Frank Eugene Vey, Chicago.....	Associate Member
Abbott L. Hayden, Chicago.....	Associate Member
Christ Jacobsen, Chicago.....	Junior Member
Walter H. Kien, Chicago.....	Junior Member

That at the meeting of the Board of Direction held September 2nd, the following applications for admission to the Society were read:

William Herbert Warner, Chicago.
 Arthur Thomas Pravdiza, Chicago.
 Joseph Otto Holzinger, Chicago.
 Frederic D. Sturges, Evanston, Ill.
 Alexander Henderson McIntosh, Chicago.
 Thomas Kenneth Myler, Chicago.
 Herbert Mertz, Chicago.

Also, that the following had been elected into membership:

Alvin T. Eunson, Chicago.....	Associate Member
Paul Shields Bailey, Gary, Ind.....	Junior Member
J. Emil Bergquist, Gary, Ind.....	Junior Member
James R. P. Kettle, Gary, Ind.....	Junior Member
Leonard Mauel, Chicago.....	Associate Member
Edwin M. Lurie, Chicago.....	Student Member
Jesse Royse Grube, Valparaiso, Ind.....	Student Member
Henry Bertram Watters, Wyoming, Ohio.....	Member
Horace B. Horton, Chicago.....	Associate Member
Mathew Elbridge Dunlap, Urbana, Ill.....	Student Member
Max Brown Higgins, Champaign, Ill.....	Student Member
Arthur Lathrup Sawyer, Gary, Ind.....	Junior Member
Ernest E. Tupes, Gary, Ind.....	Associate Member

William H. Sallwasser, Chicago.....	Junior Member
Arthur Mitchael Duff, Gary, Ind.....	Junior Member
Walter Wilkinson, Gary, Ind.....	Junior Member
Harvey Martin Hansen, Chicago.....	Junior Member

Subways was the subject for the evening, and a synopsis of the paper—abstracts of various reports on this subject, prepared by the Publication Committee—was presented by Past President O. P. Chamberlain. Mr. H. E. Bartlett, C. E., read his paper on A Primary Passenger Subway System for the City of Chicago. Discussion followed from Alderman Block, Tomaz F. Deuther (Secretary Northwest Side Commercial Association), F. E. Davidson, J. W. Mabbs, R. F. Schuchardt, and Mr. O. P. Chamberlain.

Mr. F. E. Davidson offered a motion that "in view of the importance of this subject, the discussion on Subways be taken up at a later evening, to be fixed by the Publication Committee, and that it be not closed tonight." This was amended by Mr. B. E. Grant, by adding, "if it meets with the approval of the Board of Direction," and it was so ordered. The meeting adjourned at 10:50 p. m.

Extra Meeting, September 15, 1913.

An extra meeting of the Society (No. 832) was held Monday evening, September 15, 1913.

Mr. M. O. Leighton, of Washington, had been expected to address the meeting on "The Water Power Policy of the United States," but Mr. Leighton, telegraphed Saturday, September 13, 1913, that he could not be present. Mr. Robert F. Hall, chairman of the Entertainment Committee secured Mr. Chas. H. Truax to give his illustrated lecture on "The Yellowstone Park." Mr. Hall called the meeting to order about 8:15 p. m. with about 45 members and guests present, including some half a dozen ladies. The lecture and pictures were very fine and were highly appreciated by the audience, but which was small owing to a wet night, and no general notice of the change in the program. A vote of thanks was tendered Mr. Truax at the conclusion of his address (about 10 p. m.), after which ice cream and cake were served.

J. H. WARDER, Secretary.

BOOK REVIEWS

The Books Reviewed are in the Library of this Society.

CIVIL ENGINEERS' POCKET-BOOK—A Reference Book for Engineers, Contractors and Students, containing Rules, Data, Methods, Formulas and Tables. By Albert I. Frye, S. B. M., Am. Soc. C. E., New York. D. Van Nostrand Company. Leather. Gilt edges. 4¾ by 6¾ ins. Pp. xlii. 1611. Price \$5.00, postpaid.

The engineer working in an office in a large city where reference libraries are convenient, and the engineer who has a fairly well selected library in his own office, seldom use the sort of book under review. Men so happily located are usually in the habit of consulting the works used as texts during their college course and are fortunate in being in a position where they have the shelf space and the space for the shelves, so their familiar books may be close by.

Every engineer, however, at some time in his career, and many engineers during the entire period they practice the profession, land in a situation where the library must be limited to one book, and that book must be a *vade-mecum*, an *aide-memoire*, covering almost the entire field of engineering endeavor. The field has been growing so much of late years that the pocket-book for the engineer has been developed into the electrical engineers' pocket-book, containing a few minor things of value to civil en-

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gineers and mechanical engineers; the mechanical engineers pocket-book containing a little of civil engineering and not a great deal of electrical engineering; the mining engineers' pocket-book that must contain considerable that pertains to all branches of the profession, but two-thirds of which is of value exclusively to the mining engineer; the civil engineers' pocket-book must today contain a little pertaining to mechanical engineering, considerable pertaining to electrical work, information on explosives fully up to the standard set for the mining engineer, together with items of value especially to the civil engineer as he is now known.

The items of especial value to the civil engineer have to do with railway work, location, construction and operation; street improvements, highway building, sewers and sewage disposal, water supply and water purification, sanitation in general; the design of bridges, roofs and structures generally. In addition, of course, it would not be complete without sections giving rules, data, etc., about arithmetic, algebra, geometry, trigonometry, analytic geometry, differential and integral calculus, etc. In short, all the thousand and more things that a man wants some sort of quick information about when he is out on the frontiers or in camp anywhere his work may take him. This book by Mr. Frye looks like a book into which the author has put himself and is a worthy successor to the various books that have been put forth, have enjoyed a generation of respect, and have gradually been forgotten after the authors die and no worthy hands have been found to take up the work of keeping them abreast of the times, or, perhaps have been forgotten because of the disinclination of publishers to provide revised editions so long as the old stuff sells.

Pocket-books have lately become a rather important feature of publishing houses, because every engineer wants such a book to use when he does go away from his office and because such books contain valuable tables and other information capable of daily use, even when more pretentious books of more special nature are available. Opinions of publishers, however, as to the sort of book engineers need, do not always coincide with the ideas of the men who use the books. Large sales in these days of prodigality in advertising expenditure are really not a criterion of value. The real test of the worth of a book is its value to a man when he wants information in a hurry without having to read a condensed treatise, written by a learned man who has never been placed in exactly the same situation.

While considerable may be said in favor of books divided into sections, each section prepared by an authority, such books are really text-books and liable to require more revision in the very near future than publishers feel warranted in permitting. They have also the decided disadvantage that the men who write them usually exhibit more familiarity with the literature of the subject than with the practical field and office applications. The best man to employ to prepare such a book is one of the class known as a "job chaser," whose experience has been varied and whose work has called him to many places. Such a man collects, in loose leaf form and in scrap books, the data he finds valuable to him and as he meets other engineers and trades with them his note book gradually assumes a value hardly to be measured in terms of dollars. When he finds a publisher to put this information into book form, the profession is benefited. The book under review bears every evidence of having been thus prepared. It contains many old and new tables and diagrams. A better book for the man working in places many miles, perhaps many days, distant from reference libraries can hardly be imagined. The reviewer thinks so highly of it that he has purchased a copy for his own use and has already made use of it. McC.

SMOLEY'S TABLES.—Parallel Tables of Logarithms and Squares. Diagrams for Solving Right Triangles, Angles and Logarithmic functions corresponding to given bevels. Common logarithms of numbers, tables of logarithmic and natural trigonometric functions, and other tables. For Engineers, Architects and Students, by Constantine Smoley, C. E.

Seventh edition, revised and enlarged, McGraw-Hill Book Co., New York, 1912. Flexible leather, 174 pp., 7 by 4½ in. Price \$3.50.

This book is well known, in its earlier editions, to many readers of these pages, but some additional matter has been introduced in this seventh edition. In addition to the extensive Parallel Tables of Logarithms and Squares, of feet, inches and fractions, up to 100 feet, there has been added an extension of logs and squares from zero to 16 inches, varying by one-sixty-fourth of an inch. There is also a diagram for the solution of a right triangle with a base of 16 subdivided into eighths. These are the two main additions to previous editions. The paper, typography, press work and binding are good, as has been the case in the earlier editions.

NOTES ON HEATING AND VENTILATION, by Prof. John R. Allen, University of Michigan. Third Edition, 226 pages, 6 by 9 in. Cloth bound, with tables and many illustrations. Price \$2.50.

A PRACTICAL MANUAL OF STEAM AND HOT WATER HEATING, by Edward Richmond Pierce. First Edition, 339 pages, 6 by 9 in. Illustrated. Cloth bound. Price \$2.50.

These two books, published by Domestic Engineering Co., of Chicago, are worthy of notice, and contain much valuable matter. Prof. Allen of the University of Michigan, is known to many readers of these pages. His book is based on a series of articles written originally for Domestic Engineering, in which the author showed that the subject of Heating and Ventilation could be logically developed from engineering principles. For many years the University of Michigan has been making experiments to obtain scientific information concerning the physical laws of heat that particularly concerned the heating engineer. The results of these investigations are tabulated and form a valuable part of this book. The book contains some fourteen chapters, in which the first relates to Heat Losses, and the rules for determining these in different constructions. Next comes different forms of heating systems, their advantages or disadvantages. In chapter III, the author considers the design of a direct steam heating system, and in which is presented a steam table with examples of its use, also the loss of heat from radiators and their efficiency, whether made up of one or more columns. This efficiency is also somewhat affected by the kind of paint used on the radiators. Rules are given for direct heating, with an example of a building with the calculations for the necessary radiation worked out. Following this, in Chapter IV, the indirect steam heating system is considered with illustrations of radiators and their placing. Rules for indirect heating with applications are presented. Having settled upon the amount of radiation necessary in any special case, the supply of the steam for the same is the next point and this introduces the subject of Boilers (Chapter V) and Steam Piping (Chapter VI) to convey the steam and take care of the condensation. This part of the book, with its tables and illustrations, seems to be quite complete. There are some architects and householders who favor the use of hot water instead of steam as the heating agent. The design of a hot water heating system, is the subject of Chapters VII and VIII, with tables, calculations of sizes, layout of piping, etc. Closely related to heating systems is the subject of ventilation, which is presented in Chapters IX, X and XI, with tables, calculations and illustrations. In Chapter XII, a central heating system is presented, as applied more specifically to a collection of buildings, like public institutions, rather than to a municipality. The final chapter of the book takes up the subjects, piping, covering, and sundry appliances. The book should be of value as a text and reference book for engineers engaged with heating and ventilating problems.

The second of the above books is of somewhat different character; it is more general and less technical, and would probably appeal more di-

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rectly to the steam fitter, and less to the educated engineer. The author has had many years' experience in the heating business, and as a result of this experience and his observations, he is able to advise in a practical way on a steam or hot water heating job. The author has carefully avoided the use of formulae, out of consideration to the average "fitter," but some tables are introduced, and rules for proportioning different parts, are carefully set forth.

The author first considers the size of the chimney flue, as the rate of combustion of the coal, which is the source of heat, depends upon the draft. But the author while insisting upon sufficient cross area of the chimney flue, does not give the same consideration to the effect of height of the chimney upon the draft.

To explain the subject of draft, two forms of draft gauge are illustrated, which are well enough in their way, but a far less expensive device can be made from a piece of glass tubing and which will serve the same purpose, that is to determine the draft of the chimney or flue, as measured in inches of water. Forms are shown for taking down the measurements of the several rooms, their exposure, the character of construction and the area of heat radiating surface to enable one to calculate the amount of radiation required for a steam or hot water heating job, but more than such figures the author shows the necessity of having experience and exercising judgment in making allowances for many variables, which necessarily occur in figuring on any heating job. The author very properly calls attention to the variation of the boiling point of water under varying air pressure due to difference of altitudes. For an elevated situation, as among the White Mountains, a greater amount of radiation, per unit of capacity, is necessary than at Portland or Newport, nearer sea level, other conditions, as exposure and construction, being assumed the same. The author gives some attention to the subject of piping, the layout of the risers and runs, the sizes of the pipe, the effects of fittings, elbows and tees, as influencing the flow of the steam (or hot water) and that higher pressures are necessary to overcome these restrictions. This is valuable to the contractor as he is tempted to use economy in the sizes of the pipes, etc., which may result in an unsatisfactory job to the owner. A dissatisfied customer is always a serious handicap to a contractor.

Much of the book, illustrations and text, relates to heating jobs of small or moderate dimensions, as in residences and in which cast iron boilers are frequently used. Very satisfactory results are frequently and generally obtained, in such cases, if the work is in the hands of steam heating contractors who have had experience. But with all boilers for heating purposes, and which are fired intermittently, and should hold the fire over night, the size of the firepot or furnace is of considerable importance as has been well shown by the author. The calculations involved in considering a steam (or hot water) heating job must involve the freedom for combustion of the coal, as the source of heat, which means freedom for draft (size of chimney flue) and quantity of coal available for combustion (size of furnace, or firepot). The heating value of a given coal, may be known, but what should also be known is the space necessary to hold the quantity of coal required for a given period of combustion and the freedom of transmission of the heat from this fuel to the water of the boiler.

The book is well printed and makes an attractive appearance.

PRINCIPLES OF IRRIGATION ENGINEERING, ARID LANDS, WATER-SUPPLY, STORAGE WORKS, DAMS, CANALS, WATER RIGHTS AND PRODUCTS. Frederick H. Newell and Daniel W. Murphy. McGraw-Hill Book Co., New York, 1913. 6 by 9 in., 293 pp. (including index), 16 plates and 54 figures in the text. Cloth bound. Price, \$3.00.

This is a new and valuable book, the purpose of which is to assist the

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student and the engineer, by pointing out the essential questions to which special attention must be given. In its broadest aspects, Irrigation Engineering may be defined as the development of the water resources as relating to their conservation and use. The book specifically deals with the methods of retaining, controlling, and distributing the water, needful for agriculture, and also those matters leading to financial success, to the investments thus made. The author's aim has been to furnish the information concerning the water supply and its use as applied to human needs. These views and statements are worthy of study by statesmen, capitalists and men of affairs, and engineers who may be called upon to plan irrigation works. There are nineteen chapters, which first consider irrigation and irrigable lands. Chapter III concerns water-supply, its sources, character, rainfall and runoff, measurement, etc., and amount of water required for irrigation. The design and construction of canals is the subject of Chapter IV, which is well treated. The subject of Canal Structures naturally follows in the next chapter, and in which consideration is given to permanent or temporary structures, including headgates, checks and drops, wasteways, culverts and flumes, tunnels and inverted siphons, measuring devices, and the protection of canal structures. Chapter VI takes up the subject of Distribution Systems, including the laterals, their capacity and location, flumes and pipes and accessibility to the laterals, for their maintenance.

Irrigation by pumping is the subject of Chapter VII which considers the source of supply, character of pumps and power for the same, which may be by windmills, or some other source of energy, with the cost of pumping, and its feasibility. Intimately connected with irrigation is the matter of drainage. It is an essential and the subject deserves the attention given in Chapter VIII. Following this are four chapters on Operations and Maintenance, Storage Works, Reservoir Sites and Dam Sites. Then comes four other chapters on Timber Dams, Earth Dams, Rockfill Dams and Masonry Dams. Next comes a chapter on Outlet works, which is of great importance and particularly so with High Dams, with the water under a considerable static head. The final chapters of this interesting and valuable book relate to Water Rights, and Economic Features of Irrigation. The standing of the authors and their experience in the Reclamation Service particularly fits them for such a valuable work as this treatise.

AN ELEMENTARY TREATISE ON CALCULUS, BY WILLIAM S. FRANKLIN, BARRY MAC NUTT AND ROLLIN L. CHARLES OF LEHIGH UNIVERSITY. Published by the authors, South Bethlehem, Pa., 1913; 5½ by 8¼ in.; 253 pages, and 38 pages of appendix; many text illustrations; cloth bound.

The purpose of this book is to put before readers an elementary treatise on differential and integral calculus in a style that the average student will easily comprehend, and which will make this book useful also to a class of readers who wish to acquire a knowledge of the elements of differential and integral calculus by home study.

As stated by the authors, a knowledge of elementary algebra to the binomial theorem, plane and solid geometry, trigonometry, and the most simple parts of the usual application of algebra to geometry, are the only absolute requisites for the study of this book.

The authors have preferred to separate the formal problems from the textual discussions, and have introduced a considerable number of problems and the answers to the same arranged in an appendix.

The latter feature will be found very useful by all such readers who wish to "brush up" a little on a subject which most practical men must confess is so very easily forgotten if not constantly practiced.

The chapter on vector analysis is admirably treated. As a text-book of pure mathematics this work can be warmly recommended, although from an engineer's viewpoint a greater number of actual engineering problems

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could have been treated in the textual discussions, illustrating the actual application of the principles of differential and integral calculus to actual practical problems that the engineer is most likely to meet in his practice.

R. G. R.

EXCAVATING MACHINERY. By Allen Boyer McDaniel, B. S., Asst. Prof. of Civil Engineering, University of South Dakota. McGraw-Hill Book Co., New York. Cloth, 340 pp.; 134 illustrations; XXX tables. Good index. Price, \$3.00.

Up to the present time the seeker after information on the subject of excavating and earth-moving machinery has been obliged to depend upon trade literature, and references to articles in technical papers, the latter not always being available to the men who needed the information in a hurry.

The author of this work has compiled all the matter it has been possible to secure from every source, and has presented it with information on cost, and illustrations showing operations. He has seemed determined to adhere to the policy of presenting facts and abstaining from the presentation of personal opinions. Sometimes such a policy is dictated by wisdom and sometimes from lack of definite knowledge, and this book is so prepared that one is unable to form an opinion as to the experience of the writer. This is fortunate for the reader.

The book contains 19 well illustrated chapters treating of every form of earth and rock mover advertised. At the end of each chapter is an apparently complete bibliography. This feature alone is worth the cost of the book.

While the book is fairly complete, the reviewer noticed one slip on the part of the author in the first chapter which might be corrected in a future edition, although it is not of great importance. The buck scraper is mentioned as if it and the Fresno scraper were the same thing. The old style buck scraper, still used, is a very efficient type of scraper and the Fresno was merely a development; being a combination having the cutting edge of the buck with the ease of transportation and carrying capacity of the drag, or slip, scraper. An illustration is given of a Fresno but the caption calls it a buck scraper; and the genuine buck scraper is not mentioned.

McC.

THE PRACTICAL METALLOGRAPHY OF IRON AND STEEL. By John S. G. Primrose, Member of the Iron and Steel Institution, London. The Scientific Publishing Co., Manchester, Eng.; 129 pages; $5\frac{1}{2}$ by $8\frac{1}{2}$ in., with 109 illustrations; boards. Price, 3 shillings, net.

This convenient little manual appears to be an outgrowth and development of Chap. XLIII of Sexton's *Metallurgy of Iron & Steel*, on "The Micro-structure of Iron & Steel." The author treats of the micro-structure of iron and steel in Chapter I, with a list of the micro-constituents, their characteristics, appearances, etc. Chapter II treats of the constitution of iron and steel, gray iron, white iron, the phosphide and sulphide compounds, etc. Following this comes the Heat Treatment of Iron and Steel, with the various classifications of the ferrous alloys. The micrographic examination of failures, a very important branch, is the subject of Chapter IV, and in which consideration is given to the impurities in the steel, the effect of overheating, and prolonged heating, burning, chilling, strain hardening, etc. In Appendix I, is described Metallographic Apparatus and its Manipulation, which is quite full, with instructions on the cutting and polishing of specimens, the various etching processes, microscopic work, photo-micrographs, electric furnaces and pyrometers, etching agents and metallographic accessories. In Appendix II (the final chapter) is given a bibliography of the subject of Metallography. The book should be of value to the student of the *Metallurgy of Iron and Steel*.

SIMPLIFIED FORMULAS AND TABLES, FOR FLOORS, JOISTS AND BEAMS, ROOFS, RAFTERS AND PURLINS. By N. Clifford Ricker, Prof. of Architecture, University of Illinois, Urbana, Ill. New York, 1913. John Wiley & Sons, Inc.; 6 by 9 in.; 77 pages; cloth bound. Price, \$1.50 net.

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This book is a convenient little supplement to an earlier work by the same author, "Design and Construction of Roofs," and is intended to be on the draughtsman's and computer's desk for handy reference. It gives the ordinary formulas for beams, for different conditions of loading, shows the inconvenience in use of these, and how they may be simplified. Following are general formulas for floor joist and flooring, with a table of numerical safe values for use in the formula, covering the most of the materials of construction, particularly of timber. Similarly the notation and formulas for loads on roofs, is presented with some applications to problems. Some eight pages are devoted to cast-iron lintels, with computations of safe-sections for various loads.

Following this there are several pages of condensed formula for loaded beams under different conditions, and of different materials, and which would greatly lighten the labor of computations.

CONCRETE ROADS AND PAVEMENTS. By E. S. Hanson, Editor of *The Cement Era*, Chicago., The Cement Era Publishing Co.; cloth; 227 pp.; 5 by 7½ in.; illustrated. Price, \$1.00.

Concrete roadways and pavements at the present time are exciting a great deal of attention, but nearly all the information to be obtained in book form is issued by cement manufacturers or dealers in materials used in the construction of roads. A great deal has been printed in technical periodicals which Mr. Hanson in this work makes available for the general reader and for the man who seeks unbiased data.

The author is a special writer and not an engineer so the book is free from his personal opinions, being confined to a statement of facts made by men of experience. It is remarkably free from extracts of trade literature, so is complimentary to what any engineer may obtain free for the asking. A brief description is given of every patented form of concrete pavement on the market and the final chapter contains all the standard specifications it was possible to compile. The information on costs is very full and the book is a good example of what a monograph on a practical subject should be.
McC.

AIR COMPRESSION AND TRANSMISSION. H. J. Thorkelson, M. W. S. E., Assoc. Prof. Steam and Gas Engineering, University of Wisconsin, Madison, Wis. McGraw-Hill Book Co., New York, 1913. Cloth bound; 207 pages; 6 by 9 in.; 143 illustrations in the text. Price, \$2.00.

This book, largely based on the lecture notes of the author, is a valuable addition to an engineering library. The book presents in logical order the fundamental principles of air compression and its transmission through pipes. Examples are introduced to illustrate the application of these principles and to make clear the methods of calculations of problems, dealing with air under various pressures. Such knowledge is necessary to enable an engineer to comprehend the advantages and limitations of various systems which may be used to secure a desired pressure, and to use this air under pressure as a medium for conveying or transmitting energy. After an Introduction, in Chap. I, the characteristics of air are given, as vapor in air, relation between pressure and temperature, etc. Then in Chap. II, is given Fundamental Definitions of Work, Energy, Heat, Temperature, Specific Heat, at constant pressure and constant volume, also as real and apparent specific heat. In Chap. III, the author takes up Characteristic and Energy Equations for Air, as Boyle's Law, Equation for perfect gases, work of Isothermal change and Adiabatic change, etc. Graphical Diagrams, is the subject of Chap. IV, with the construction of isothermal and exponential curves; difference between isothermal and adiabatic compression, etc. In Chap. V, consideration is given to air at pressures below that of the atmosphere, with illustrated descriptions of various types of air pumps. One important use of lessening the tension of the atmosphere is in lowering the temperature of evaporation of liquids, as in concentration of liquors, cane-juice and the like.

Air at Low Pressure as obtained by some form of fan, is used in many

industries, as in forges, foundries, ventilation of halls, assembly rooms, shops, etc., and is treated at some length in Chap. VI, with illustrations and diagrams, and includes a valuable lecture, by H. deB. Parsons, at Columbia University.

In Chap. VII the author treats of air under higher pressure as obtained by Piston Compressors, and this is further elaborated in the succeeding chapters, on Efficiencies and Energy Compensation. Multi-stage Compression with Details, of Piston Air Compressors, and Turbo-Compressors. The Hydraulic Compression of Air of Chap. XII, has long been known and used, and is of much service in some places, though the efficiency is not high, and has the disadvantage that the compressed air, so obtained carries a good deal of moisture.

The effect of altitude on air compression, and the testing of air-compressions under such conditions, is the subject of Chap. XIII. Altitude affects the work of air compression both in capacity and in power consumption, and is set forth at some length in this chapter. The final chapters, XIV and XV, of this book, relate to Air-receivers, Measurement and Transmission of Compressed Air, and the Selection and Care of Air Compressors. The book should be of considerable value as a text-book in an engineering course of study.

LIBRARY NOTES

The Library Committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts, the following publications have been received:

MISCELLANEOUS GIFTS.

- E. E. R. Tratman, M. W. S. E.:
8 pamphlets and 2 bound volumes.
Onward Bates, M. W. S. E.:
11 bound volumes and 7 pamphlets.
Ernest McCullough, M. W. S. E.:
4 pamphlets.

EXCHANGES.

- St. Paul Commissioner of Public Works:
Annual Report, 1912. Pam.
Maine Commissioner of Highways:
Eighth Annual Report, 1912. Cloth.
Columbus, Ohio, Division of Water:
Annual Report, 1912. Pam.
Western Australian Institution of Engineers:
Proceedings, November, 1912. Pam.
Illinois Coal Mining Investigations:
Preliminary Report on Organization and Method, etc. Pam.
Iowa Engineering Society:
Proceedings 25th Annual Meeting, February, 1913. Pam.
American Mining Congress:
Report of 15th Annual Session, November, 1912. Pam.
University of Pittsburgh:
Bibliography of Smoke and Smoke Prevention. Pam.
Connecticut Society of Civil Engineers:
Proceedings, 1913. Pam.
Kansas Engineering Society:
Transactions, 1913. Pam.

- American Electrochemical Society:
Transactions, 1913. Pam.
- International Association of Navigation Congresses:
Proceedings of the XIIth Congress, Philadelphia, 1912. Cloth.
- American Society of Mechanical Engineers:
Transactions, 1912. $\frac{1}{2}$ leather.
- New York City Board of Water Supply:
Seventh Annual Report, 1912. Cloth.
- Chicago Department of Public Works:
37th Annual Report, 1912. Cloth.
- Ontario Land Surveyors:
Proceedings 21st Annual Meeting, 1913. Pam.
- Illinois Railroad and Warehouse Commission:
Annual Reports, 1911 and 1912. 2 vols. Cloth.
Railroad Map of Illinois.
Decisions and Opinions, 1889-1912. Cloth.
- American Society for Testing Materials:
Index to Proceedings Vols. I-XII, incl. Cloth.
- Utah Conservation Commission:
First Biennial Report, 1913. Pam.
- International Railway Fuel Association:
Proceedings 5th Annual Convention, 1913. Pam.
- Society for the Promotion of Engineering Education:
Proceedings, 1912, Part II. Cloth.
- New York City Board of Water Supply:
Long Island Sources, Vols. I & II. Cloth.
- Chicago Department of Electricity:
Report of Department, 1912. Pam.
- Metropolitan Water and Sewerage Board, New York:
12th Annual Report, 1912. Cloth.
- New York Public Service Commission, First District:
New Subways for New York, 1913. Pam.
- New York Board of Water Supply:
6th Annual Report, 1912. Cloth.
- Canadian Society of Civil Engineers:
Report of Annual Meeting, 1913. Pam.
- John Wiley & Sons:
The Improvement of Rivers, Thomas and Watt. 2nd ed. 2 vols. Cloth.
Igneous Rocks, John P. Iddings. Vol. II. Cloth.
- Scientific Publishing Co.:
Practical Alternating Currents, Smith. 5th ed. Cloth.
Engineering Tables and Data, Pullen. Cloth.
The Practical Metallography of Iron and Steel. Primrose. Buckram.
- McGraw-Hill Book Co:
Excavating Machinery, A. B. McDaniel. Cloth.
- Wolcott C. Foster:
A Treatise on Wooden Trestle Bridges, Foster. 4th ed. Cloth.
- D. VanNostrand Co.:
Electrical Engineer's Pocket-Book, Foster. 7th ed. Leather.
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2 cloth.
- Grain Dealers Journal:
Plans of Grain Elevators. Cloth:
September, 1913.

Chapman & Hall, Ltd.:

Theory and Design of Structures, E. S. Andrews. Cloth.
 Further Problems in the Theory and Design of Structures, E. S. Andrews. Cloth.

The Macmillan Company:

The Life and Work of Edward A. Moseley, James Morgan. Cloth.

Yale University Press:

Conservation of Water, Walter McCulloh. Cloth.

Building Ordinances:

Baltimore, Duluth, Indianapolis, Little Rock, Madison, Memphis,
 Montreal, Nashville, Portland, Quebec, Syracuse, Winnipeg.

First National Bank of Chicago:

A Brief History, 1863-1913. Cloth.

York, Pa., Engineering Society:

Proceedings, 1910, Vol. I. Paper.

GOVERNMENT PUBLICATIONS.

Commissioner of Education:

Report, 1912. Vols. I & II. 2 cloth.

U. S. Geological Survey:

The Production of Chromic Iron Ore in 1912. Pam.

The Production of Gems and Precious Stones in 1912. Pam.

The Production of Peat in 1912. Pam.

The Production of Barytes in 1912. Pam.

The Production of Fullers Earth in 1912. Pam.

The Production of Asphalt, Related Bitumens, and Bituminous Rock
 in 1912.

The Production of Asbestos in 1912. Pam.

The Production of Antimony, Arsenic, Bismuth and Selenium in
 1912. Pam.

The Production of Talc and Soapstone in 1912. Pam.

The Production of Phosphate Rock in 1912. Pam.

The Production of Sand and Gravel in 1912. Pam.

The Production of Magnesite in 1912. Pam.

The Production of Manganese and Manganiferous Ores in 1912.
 Pam.

The Production of Salt and Bromine in 1912. Pam.

The Production of Borax in 1912. Pam.

U. S. Department of Agriculture:

Report of Chief of Weather Bureau, 1910-11, 1911-12. 2 cloth.

Various Bulletins of Forest Service, Bureau of Chemistry, Forest
 Service, Public Roads, etc.

U. S. Bureau of Mines:

Various Bulletins and Technical Papers.

U. S. War Department:

Annual Reports 1912, 4 vols. Cloth.

Report of Tests of Metals, 1912. Cloth.

U. S. Geological Survey:

Sundry Bulletins and Water Supply Papers.

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THE DECORATIVE POSSIBILITIES OF CONCRETE

C. W. BOYNTON, M. W. S. E., and J. H. LIBBERTON, ASSOC. W. S. E.

Presented June 16, 1913.

In the early days of construction, the architect and engineer appeared in the work under the title of master-mason. This individual wore long robes as an indication of his authority, and the designs on his trestle board are a matter of history. With the passing of the master-mason came the architect and engineer, the one a worker in lines, and the other a worker in figures.

The combination is ideal; one specializing on beauty and the other, safety and efficiency. Too often, however, safety and efficiency receive first consideration, and the beauty only gets its share after costs have been carefully calculated.

In reality, the most common buildings of a manufacturing type can be made to conform to pleasing lines without the additional expenditure sometimes thought necessary. After pleasing lines have been determined, then comes the question of decoration. In many instances this is carried to extremes and we find exquisite examples of stone carving and cornice work being placed at the top of an eighteen or twenty-story office building, which no one can see or appreciate except a possible few located in the offices upon the opposite side of the street.

This may be said of the Chicago Post-office (Fig. 1), with the exception that here the entire structure has been injudiciously placed. It is well recognized that a structure of this kind occupies a maximum ground area with a minimum return in floor space and light area. This building was a large undertaking from an engineering standpoint, but whether or not it is an architectural success, few may judge because of the impossibility of viewing the entire building at one time. Of the same type is the Capitol at Washington, but so judiciously has it been placed that a full view may be obtained from all sides without obstruction. In the open, or upon the crest of a hill, the Chicago Post-office, even though inefficient in design, would be architecturally beautiful.

There is an old maxim to the effect that the designer should ornament his construction and not construct his ornamentation. This is an admirable saying, but should be subordinated to another

rule, that he should ornament his structure only if he lacked the skill to make it beautiful in itself. A structure of any kind that is intended to serve a useful end, should have the beauty of appropriateness for the purpose it is to serve. It should tell the truth, and if the character were such that it can be permitted to tell the

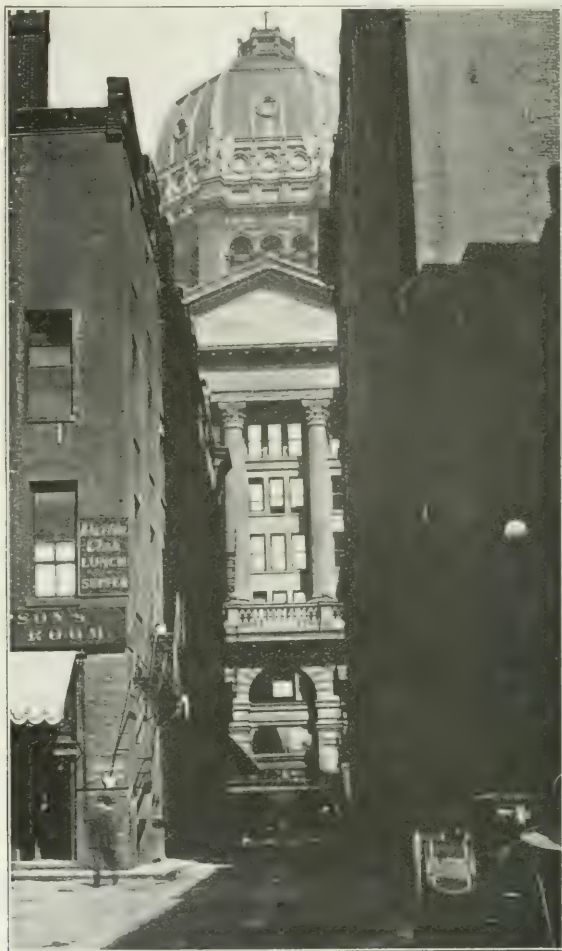


Fig. 1.—Chicago Postoffice, West Front.

whole truth, so much the better. It should preferably be beautiful and not beautified.

There is a certain charm about a massive structure almost irrespective of design. The sight of a pyramid on the desk would call

forth no expression of interest or enthusiasm, but let this grow in size until it assumes the proportions of those famous structures of Egypt and many pilgrimages will be made to view it. Of course the Egyptian pyramids are assumed to be the resting place of kings, and the placing of the blocks required the use of more muscle or machinery than we at present have any knowledge of,

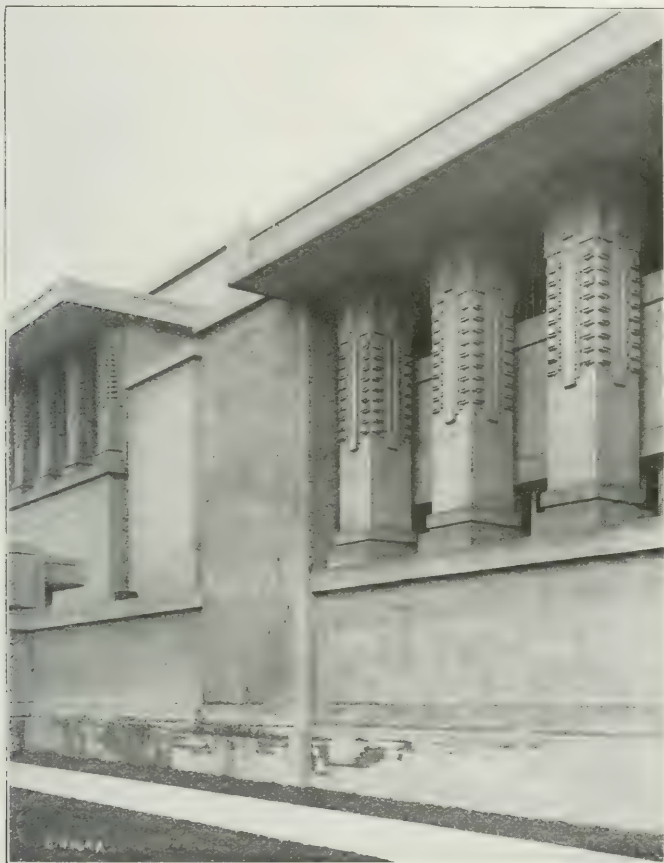


Fig. 2.—Detail of Unity Church, Oak Park, Illinois.

but our idea of their beauty and grandeur obtains primarily from the immensity of the structures.

There is no reason, however, why mass should not be combined with decoration, provided the design is not made subordinate to the decoration. This combination has often been used very effectively. The question is, what medium shall be chosen? At the Unity Church, Oak Park (Fig. 2), the building is not only monolithic concrete but

the ornamentation partakes of the same characteristics, having been cast at the same time and of the same material. In a building of this type, however, much attempt at decoration would be fatal and the unobtrusive style adopted detracts not in the slightest from the dignity obtained by large areas and massive construction. With a different style of building, such as the Administration Building at Washington Park (Fig. 3), the treatment may be entirely different and the concrete be called on to assume the most intricate shapes.

Both of these buildings show the same surface finish. The architecture determines the decoration. With conditions reversed and the decorations transposed, the effect would be ludicrous. In



Fig. 3.—Concrete in the Administration Building and Balustrade, Washington Park, Chicago.

these buildings the monotony of the form concrete has been relieved by the use of a rather dry surface mixture which discloses the nature of the aggregate used. In work of this kind, particular attention must be paid to methods of obtaining uniformity of surface and absence of horizontal joint markings (Fig. 4), although the latter blemish is not nearly so noticeable on work of this character as with the wet mixture.

After all, the question of pleasing effects depends not only on the surfaces and the surface treatment, but on the combination of design with the surface texture. Compare, for instance, the factory of the Carter's Ink Company with that of the Piqua Hosiery Com-

pany (Fig. 5). Both have been finished with the same tools but the former shows infinitely more work without obtaining a pleasing effect. The difference seems to lie mainly in the appreciation of the possibilities in a molded material. A number of large surfaces have been substituted for the cut-up stone effect and the judicious use of



Fig. 4.—Entrance Detail. Administration Building of the South Park Commissioners, Washington Park, Chicago.

the bush hammer has accentuated the massive and graceful design of the building (Fig. 6). And this effect has been achieved without any expensive decoration or form work other than would be required for the most simple structure of reinforced concrete. On a smaller building, such as a subway entrance in Boston (Fig. 7), the method of dividing off the panels is more pleasing, possibly because the



Fig. 5.—Manufacturing Building of the Piqua Hosiery Co., Piqua, Ohio.



Fig. 6.—Detail of Entrance to the Building of the Piqua Hosiery Co., Piqua, Ohio.

proportion of small areas to the whole is so much greater. Nevertheless, you will agree that the method of treatment used on the Piqua building is even superior on a small structure, such as the Weston Fire Station (Fig. 8), where also the panels have been bush hammered, preserving the corners and margins intact. Consistent with its purpose, the entire structure is of reinforced concrete.

When not carried to extremes, the judicious use of a few division marks, such as have been employed by the Witherbee Sherman Company in its power station (Fig. 9), relieves the plainness of design and forms a rather interesting framework for what would otherwise be a monotonous surface. Had the block surface been carried across the entire wall, the pleasing effect would have been ruined.

No doubt everyone is familiar with what seems to be the proverbial small town water supply tank, with its hemispherical bottom and



Fig. 7.—Subway Entrance, Boston.

sprawling legs; anything but an ornament in the community. This same type of structure was installed at Gary, Indiana (Fig. 10), but so well has it been concealed that the tower is a thing of beauty and possesses real architectural merit. The work of molding so large a structure in reinforced concrete was greater because of the forms required, the total height being 125 ft. But the finished structure justified the labor. The lower 25 ft. and the upper cornice are of cast concrete stone, made by George Rackle & Sons of Cleveland. The remainder is of reinforced concrete. The relief for the surface monotony is seen in the decorative work at the top and base.

Decoration, however, is not an essential of mass construction, as has been clearly demonstrated by the Spanish in the design of the adobe dwellings and missions. But adobe perishes and our interesting relics of former days will soon be a thing of the past. Noting

the possibilities of monolithic concrete for preserving this architecture, Frank Miller has undertaken to petrify indefinitely, as it were, some of the most interesting details of the mission architecture developed by the Franciscan Fathers in California (Fig. 11). Thus when the last adobe wall has crumbled we still shall have a replica of the Campanile of San Gabriel (Fig. 12) and the imposing arches of San Fernando, these having been duplicated in the Glenwood



Fig. 8.—Weston Fire Station, Weston, Mass.

Inn at Riverside, California. Little other material than concrete has been employed—except the roof tile, which undoubtedly lend color to the scheme and interest to the picture. On the roof is a famous collection of bells, over 300, dating back to 1278. It seems, consequently, particularly fitting that these old relics, after their furious experiences, may now rest content, enclosed

and surrounded by a structural material which will preserve their last resting place intact through the centuries to come.

Of a mission type, also, are the rest or way stations of the Pacific Electric Railway, at Pasadena, California. These are fast replacing the old wooden rough and ready stations, none of which was consistent with the high class residential district through which the company operated. On both sides, a bench is built into the wall so as always to furnish protection from rain.



Fig. 9.—Power House, Witherbee Sherman, Port Henry, N. Y.

An unexpected test of building materials presented itself during the San Francisco earthquake, and the architect for the delightful bell tower on the Mills College campus, Miss Julia Morgan, states that it was one of the few buildings which remained undamaged in that vicinity (Fig. 13).

Because it includes some of the most notable sculpture on the coast, the building of the Throop Polytechnic Institute at Los Angeles, Cal., may have interest (Fig. 14). It is all of reinforced

concrete even to the tower, and was designed by Myron Hunt, of Los Angeles. The sculpture was executed in New York and cast in glue molds by a local company, the cost of this one item being something over \$5,000. Warm climates seem particularly suited to



Fig. 10.—Gary Water Tower, Gary, Indiana.

plain concrete construction, and its general adoption may partially be explained by the cool appearance of the plain surface.

Concrete, still in its formative state of development, is a comparatively new architectural material, although structurally it has been proving its permanence for many years. The particular reason



Fig. 11.—Courtyard, Glenwood Inn, Riverside, Cal.



Fig. 12.—Glenwood Inn, Riverside, Cal., Looking from the Street into the Courtyard.

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Fig. 14.—Throop Polytechnic Institute, Los Angeles, Cal.



Fig. 15.—Pouring Concrete Floor with Panel Inserts of Molded Sand or Plaster.



FIGURE 13.
BELL TOWER, MILLS COLLEGE, CAL.



FIGURE 32.
OFFICE BUILDING, FORD AUTOMOBILE CO., DETROIT

for gratification comes in the new discoveries, and new uses to which it is continually being put. Every day there arises some Philistine who has discovered something new and worthy of consideration.

Frederick Squires, of New York City, had viewed with regret the present slab and beam floor construction. After several years of study, he devised a method of duplicating the most intricate of cast ceilings in solid concrete, with a decided saving of material. His scheme consists simply in employing reverse coffers of moulder's sand (Fig. 15) which are placed on the form before the concrete is poured. When the forms are removed, the panels are exposed, the whole being accomplished in one operation. Far more pleasing surfaces are obtained than were ever presented by the old plaster-of-paris method of applying previously cast panels to the work (Fig. 16).

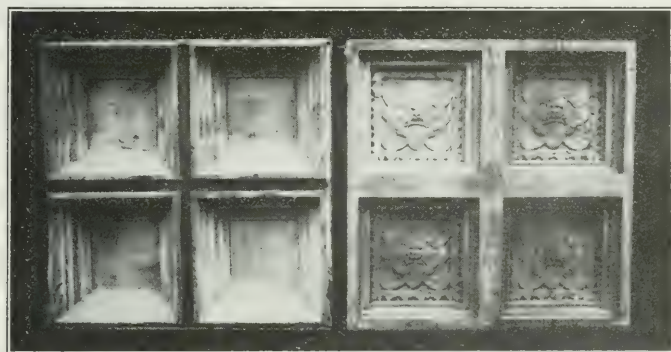


Fig. 16.—Sample of Paneled Ceiling Work Done with Sand or Plaster Molds.

A few years ago the theory of applying concrete by means of a hose and nozzle met with derision, but every day we hear of more work being done by this method, the machine being designated as the "cement gun" and the concrete "gunite." An interesting piece of work has been accomplished by the Boston Elevated Railroad at the foot of O Street, Boston, where a garden fence has been constructed by this method. The base and posts are built of concrete poured into the forms in the usual way, the posts being relieved by protecting brick quoins (Fig. 17). The street face of the panels were shaped by means of a wooden form and each central panel was faced with steel. The concrete was applied from the rear with the cement gun, making the panels $2\frac{1}{2}$ in. thick and the styles 4 in. thick. The interesting point in the operation is that the entire panels are made in one piece and at one operation.

The very fact that concrete is simple in operation has caused many to undertake construction who are in no way fitted to carry it

out, but with proper supervision even the most unskilled laborer can accomplish pleasing results. This has been proved conclusively by the work of the Aberthaw Construction Company at Port Antonio, Jamaica (Fig. 18). The 56 columns for the structure were cast in sand molds, then put into a lathe and turned down and polished so as to expose the coarse aggregate. An intensely red coloring matter present in the natural aggregate has given the walls a light salmon tint, which is very attractive. Particular attention is directed to the methods of elevating the concrete to the work, and judging from the smiling faces of the women shown in Fig. 19, the task does not seem to be over-tedious. For this hard labor they receive about 25c per day. Able-bodied men on the same work receive about twice this amount. Even with the lack of artistic appreciation

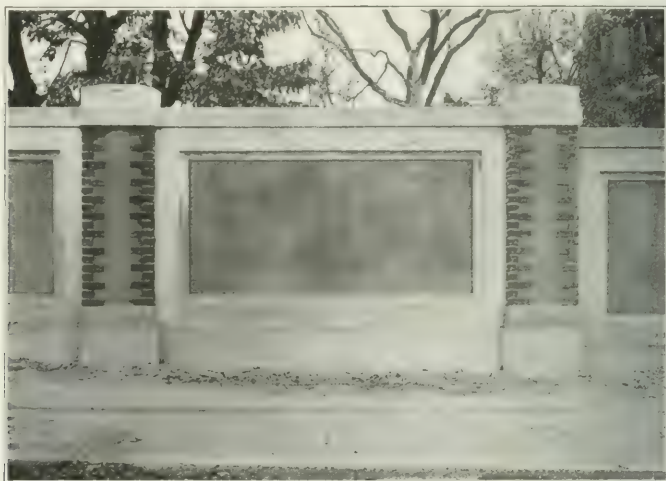


Fig. 17.—Cement Gun Construction on Wall of the Boston Elevated Railway.

which the people of this class possess, the building has been designed so as to be architecturally pleasing and will undoubtedly have its effect in educating the people to a better realization of what constitutes good architecture and design.

A building should be fitted to the country in which it is to be located, and more and more attention is continually being given to the unity which must exist between the landscape and the layout of concrete structures which are to be added as permanent improvements. A striking example of this is to be found on the Duke Estate at Somerville, N. J. (Fig. 20), where white cement and white sand have been used in facing the concrete, in order, possibly, to give more contrast against the natural beauty of the surroundings. The bridge (Fig. 21) harmonizes with the rest of the work but might be improved if the surface markings were eliminated—the general

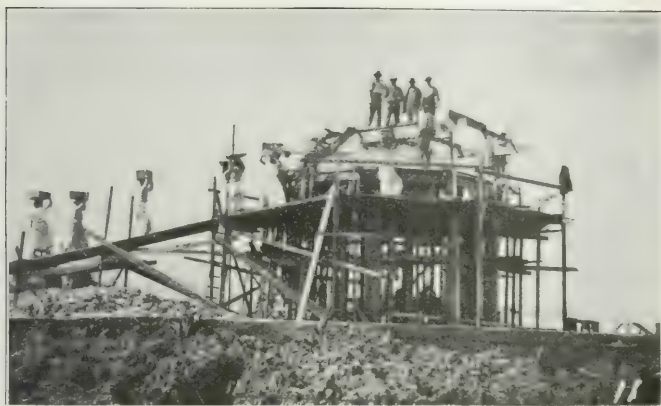


Fig. 18.—Concrete Construction in Jamaica, Showing the Method of Elevating Concrete.



Fig. 19.—Concrete Elevators on Construction Work in Jamaica.

lines accentuated by bush hammering, or some one of the other numerous interesting surface treatments, to which concrete may be subjected.

In a similar manner the concrete posts which have been added to the Lake Shore Drive in Chicago, not only add materially to the dignity and beauty of this boulevard but are, themselves, better set off by being so well located (Fig. 22). Imagine this particular design on South Clark and Harrison Streets. For a while the posts would look entirely out of harmony with their surroundings, but there is every probability that their advent would produce a desire on the part of the property owners to clean up the streets and buildings so as better to accord with the dignity of the lamp standards.

A note on the method of construction of these poles may be of interest since they are of reinforced concrete, cast in one piece including the base (Fig. 23). The surfacing is made of a special mixture of cement, dark red Wisconsin granite, and a small amount



Fig. 20.—Concrete Retaining Wall and Balustrade on Duke Estate, Somerville, N. J.

of mica, which is washed, after removing from the mold, with a weak solution of hydrochloric acid. The design is the result of a contest in the Chicago Architectural Club, the successful contestant being John Hamilton.

Of a similar nature is the work on the concrete railing around Jackson Park Harbor, also in Chicago (Fig. 24). Here, as before, the concrete depends for its beauty upon the surroundings rather than upon the excellence of the design, although it is well agreed that little could be added which would improve the dignity and solidity indicated by this superior example of a concrete railing. The white surface is obtained by the use of limestone screenings which emphasizes the important part the aggregate plays in determining the color of the concrete into which it enters.



Fig. 21.—Concrete Arch Bridge on the Duke Estate,
Somerville, N. J.



Fig. 22.—Lake Shore Drive, Chicago, with Concrete Lamp Standards.

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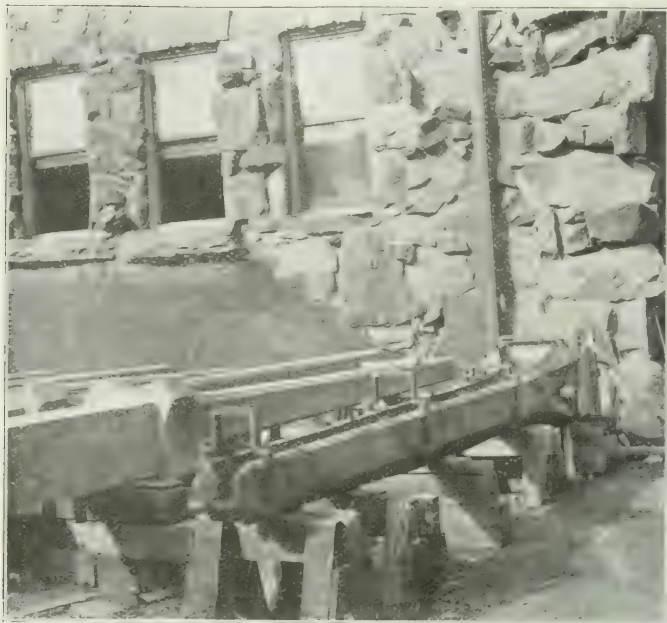


Fig. 23.—Steel Molds for Casting Concrete Poles.



Fig. 24.—Concrete Railing Around Entrance to Jackson Park Harbor, Chicago.



Fig. 25.—Independence Boulevard Viaduct, Baltimore and Ohio Railway, Chicago.

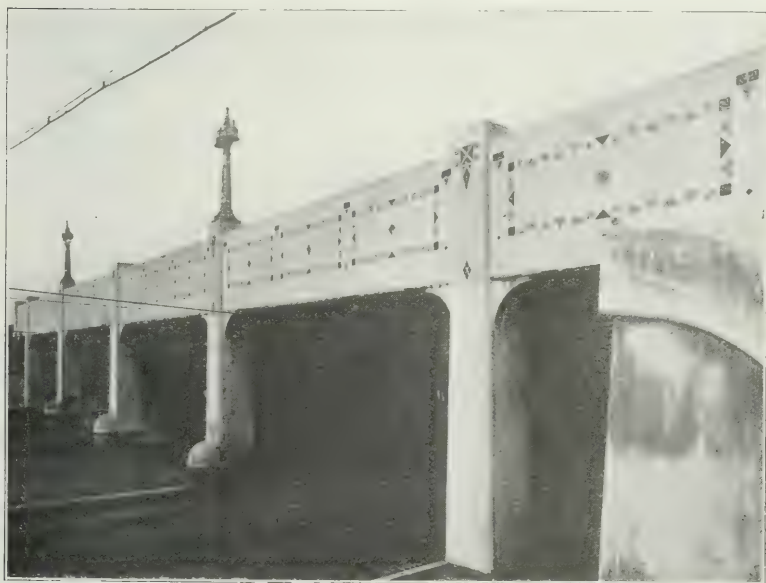


Fig. 26.—Ogden Avenue Viaduct, Baltimore and Ohio Railroad, Chicago, Showing Tile Inserts.
October, 1913

The attention which is being paid to the design of improvements which will harmonize with the surroundings may well be illustrated by the work of the B. & O. Railroad, on its Independence Boulevard viaduct, Chicago (Fig. 25). A total of some twelve to fifteen different designs were prepared and only after careful consideration was one finally decided upon, which the railroad officials thought would be suitable to submit to the Park Board. How well they succeeded is evident. Were the plain steel structure considered by itself, a realization could be had of the tremendous improvement which has been effected by the simple addition of the reinforced concrete covering. Some of the earlier work of the B. & O. Railroad shows an entirely different method of handling concrete, depending



Fig. 27.—Sacramento Boulevard Viaduct, Baltimore and Ohio Railroad, Chicago.

upon inlaid tile for decoration rather than upon the excellence of the design (Fig. 26). Of course, as this bridge is located on West Ogden Avenue, Chicago, there is nothing in the way of beautiful landscape to mention and probably the officials believed that a little brightening of the concrete surface would relieve the monotony of a busy business street. But work of this kind is extremely expensive and can best be illustrated by a comparison of this bridge with the Independence Boulevard structure which is of 250-ft. span.

The Ogden Avenue Viaduct is 135 ft. between abutments, and yet the cost of concrete finish and inlay tile was greater than the total for the other structure of 250-ft. span. A simpler structure has been designed for Sacramento Boulevard (Fig. 27), but as this street is much narrower than Independence Boulevard, naturally an

entirely different method of treatment was necessary and the lines have been made to follow somewhat along the Mission style.

Concrete surfacing not only protects the steel, making painting unnecessary, but it improves the general aspect of the structure. This is well illustrated by a very unimposing viaduct in Pittsburgh which recently was found to be rusting away for lack of paint. Feeling that the structure's existence was justified, the officials made arrangements to cover the steel with concrete, in much the same manner as has been used by the B. & O. Railroad, although no particular attempt was made at architectural effect. Nevertheless, the appearance of the viaduct has been improved and its life undoubtedly materially lengthened.

Another railroad which is paying particular attention to the appearance of its viaducts is the New York, Chicago & St. Louis Railroad, under the supervision of A. J. Himes, Engineer of Grade



Fig. 28.—Euclid Avenue Viaduct, New York, Chicago & St. Louis Railroad, Cleveland, Ohio.

Elimination. In the majority of instances the attempts have been thoroughly successful, although at Maysfield Road, Cleveland, the structure may be questioned as to its pleasing architecture. A great number of arches with short columns has not only made a large amount of form work necessary but has hardly justified the expense involved.

More pleasing work has been accomplished on the Euclid Avenue Bridge and at probably less unit expense (Fig. 28). In Cleveland also, attention has been paid to the combination of landscape with structure, as indicated by the East Boulevard Bridge (Fig. 29), which is particularly well located so far as the contour and beauty of the surrounding country is concerned. The color which has been added to the arch and abutments tends only to brighten the picture

and improve the general impression. The paneling for this bridge has all been finished with a bush hammer and the red framing was obtained by mixing iron oxide with the concrete.

As has been stated, massive structures are impressive, irrespective of their design or location, but the interest is generally enlivened by such a waterfall and stream as is included in the photograph of the concrete bridge at Spokane, Washington (Fig. 30). The design is undoubtedly excellent and would stand alone, uncriticized, but the touch of romance which the scenery furnishes engages the attention and makes the picture more alluring than that of the Paulinskill Viaduct of the Lackawanna Railroad at Hainesburgh, N. J. Though equally well designed, it is surrounded by uninteresting prairie on every side, which, of course, cannot by any means be charged against the bridge design.

Notwithstanding the excellent decorative work which has been done in plain and reinforced concrete, there are, nevertheless, numer-



Fig. 29.—East Boulevard Bridge, New York, Chicago & St. Louis Railroad, Cleveland, Ohio.

ous advocates of tile decoration. Instances are many where the use of brick or tile emphasizes the contour and enlivens the surface at very little expense. A little touch of color relieves the monotony of a single toned exterior and is illustrated in the seed warehouse of Otto Schwill & Co. at Memphis, Tennessee. This building would undoubtedly be equally as efficient were it built without any attention to pleasing architectural effects. With the present leaning toward pleasant work rooms for employes, this idea has spread to the exterior with the result that our factories are surrounded by grass plots and gardens and the buildings themselves, so far as possible, are made to conform with the tendency toward providing pleasant environment.

The office building of the Packard Automobile Company at Buffalo, New York (Fig. 31), is an equally good example of the combination of concrete and brick, although the decoration is of cast



Fig. 30.—Concrete Arch Bridge, Spokane, Wash.



Fig. 31.—Office Building, Packard Automobile Company, Buffalo, N. Y.

concrete. Carrying this idea further, the Ford Automobile Company at Detroit, has not only built of reinforced concrete with brick inlay and corner towers but has called in mosaic tile to brighten up the panels under the cornice, and though the embellishment was achieved at some expense, the architect felt that the attention to this detail was deserved (Fig. 32).

Another example of the use of colored clay tile for concrete decoration is to be found in Minneapolis, where on the north shore of Lake Calhoun a large building has been constructed of reinforced concrete, called the Calhoun Baths (Fig. 33). The central portion of the building is roofed and serves as the entrance, housing the ticket office, the rooms where bathing suits, towels, and keys to lockers are distributed, and the refectory. It also connects directly with the terrace above the bathing beach. The dressing rooms on the opposite side of the central portion of the building are without

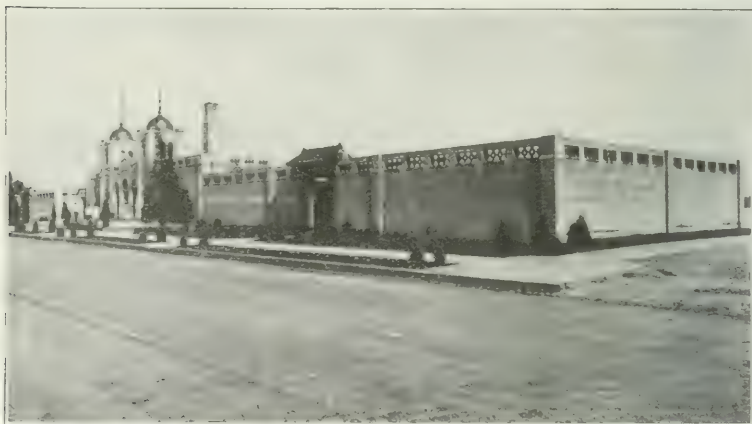


Fig. 33.—General View of Calhoun Baths, Minn.

roof but are fitted with concrete rooms and steel lockers in double tiers. In order to reach the beach, the bathers must pass through a pool of water and through a triple shower direct from above and from both sides, so that a partial wetting is received before reaching the beach.

The concrete was deposited rather dry in order to obtain a rough finish, and the form marks do not seem to detract in any way from the pleasing surface made by the coarse aggregate (Fig. 34). The decorations are of brick and clay tile, the brick having been placed when the concrete was poured, but the tile subsequently, space being made for them by tacking wooden shapes to the inside of the form. The design and construction for this building were handled by Chapman & Magney of Minneapolis.

It is not surprising that an individual directly connected with the



FIGURE 34.
CALHOUN BATHS, MINNEAPOLIS

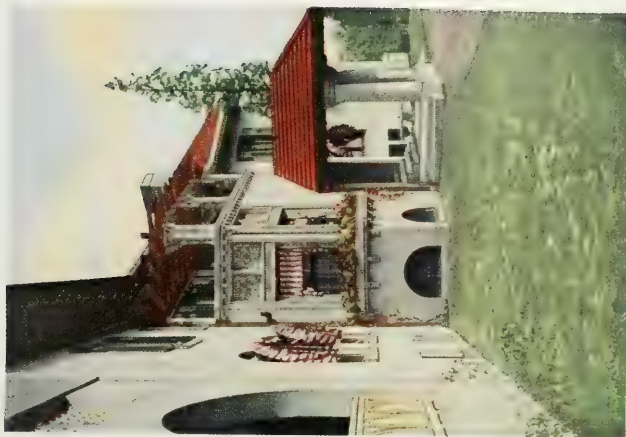


FIGURE 37.
RESIDENCE OF CHARLES E. RUSHMORE
WOODBURY FALLS, N. Y.

cement industry as is Albert Moyer, should build of concrete, nor is it surprising that one who is so well versed in concrete construction should obtain very pleasing effects as indicated by the work on his residence at South Orange, New Jersey. Liberal use has been made of exposed aggregates, employing a mixture of Portland cement with limestone screenings, marble chips, and dark trap rock (Fig. 35). Not stopping here, much dependence has been placed upon Moravian pottery decoration, which harmonizes well with the concrete surface, as is shown in the fireplace, with its inlaid panel showing an Indian at a fire, whether warming his hands or starting the blaze being not self-evident (Fig. 36). The balcony, also, has

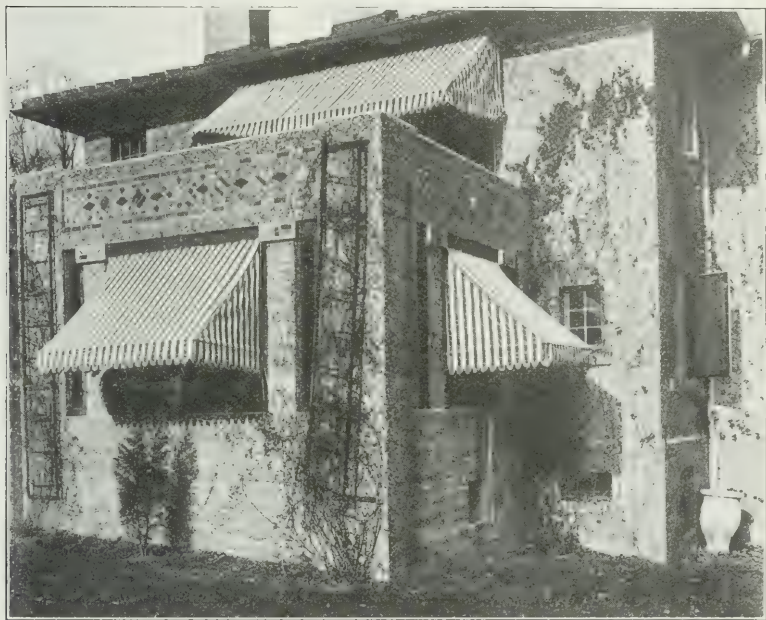


Fig. 35.—Porch Detail, Residence of Albert Moyer, South Orange, N. J.

been worked out in pottery but somewhat differently than the fireplace. The distinguishing feature lies in the fact that instead of being inlaid, the figure comes out in bas-relief and although somewhat serpentine in design, seems fairly consistent with the grape-vine motive. Undoubtedly this panel would be somewhat softened to its improvement by the ivy which was evidently not in leaf when the picture was taken.

For some time, Alfred Hopkins, of New York City, has been a strong advocate of reinforced concrete for the construction of buildings and has added a large amount of information to our knowledge of the concrete of the old Romans, having investigated this point

personally and in some detail. Nevertheless, Mr. Hopkins has never brought himself to believe that concrete should be used for the ornamentation upon buildings of the same material. For this purpose he advocates terra cotta, and judging from the excellent work which he has achieved on the residence of Charles E. Rushmore, there is reason in his contention (Fig. 37). This building is all of reinforced concrete to the roof and part of this has been constructed of concrete slabs. But for the panels and column capitals, Mr. Hopkins



Fig. 36.—Fireplace in the Home of Albert Moyer, South Orange, N. J.

has turned to terra cotta tile, with excellent results. For the average individual, of course, a detail of this kind would be prohibitive in cost. But with such a sized undertaking as this mammoth residence, the high individual cost of these panels (Fig. 38) is small when compared with the total cost of the building. However, with the advances which are being made in the use of colored aggregates, it is generally possible to obtain all the color variations necessary in the concrete itself.



Fig. 38.—Porch Detail, Residence of Chas. E. Rushmore, Woodbury Falls, N. Y.



Fig. 39.—Cement Stucco Residence of L. G. Stumer, Chicago.

It is not customary to build reinforced concrete roofs of the pitch type. In fact, there is no sensible reason for adhering to this construction when designing reinforced concrete (Fig. 39). The ideal concrete house is built with a flat roof not only because architecturally the design may be made pleasing, but because this type is the most economical in cost and space. An attic is of little use except for the storage of material which, in the majority of instances, will never be needed again, and when stored away in an attic corner, invites spontaneous combustion. Reinforced concrete has brought with it a new architecture and the sooner we appreciate its value, the earlier will be the general adoption of reinforced concrete for residences as well as the endless other types of construction to which it has already been applied.

Within the last few years, there has been a decided leaning



Fig. 40.—Forest Hills Gardens, New York.

toward the community settlement idea, and with this in view, the Forest Hills Gardens were designed (Fig. 40), not, as many people have inferred, an endowed neighborhood where buildings have been erected to house working people, but a business investment of the Russell Sage Foundation Company. It is in no sense managed as a charity, for whoever deals with it is expected to pay fair value for everything received. It is, however, an attempt to solve the housing problem for persons of modest means and its development will consequently be watched with interest. Perhaps this is the first example in America, where an absolutely barren site has been taken and treated along the lines of modern methods of town planning. Throughout the village, advantage has been taken of practically every structural material for building the dwellings, but a large part



FIGURE 41
RESIDENCE OF GAGE E. TARBELL, NASSAU BLVD., L. I.



FIGURE 46.
INTERIOR SECOND NATIONAL BANK, BOSTON
SHOWING CONCRETE BLOCK INTERIOR

of the improvements has been worked out in concrete, including the railroad station, the city market, and many of the individual dwellings as well as garden walls, foundations and the like.

Oswald Hering has utilized lattice work on one of his most important dwellings in combination with decoration of molded concrete. But where Mr. Hopkins would use terra cotta, as in the panel inserts, Mr. Hering has used concrete, depending upon exposed aggregate to furnish the touch of color needed. Attention is directed to detail view of the summer house (Fig. 41), which better shows the green lattice harmonizing so well with the trees surrounding it upon every side. Within, the lattice idea has been continued, but in an entirely novel manner by simply stenciling the lines



Fig. 42.—Interior of Gage E. Tarbell's Residence, Garden City, L. I., Showing Substitution of Fresco for Lattice.

upon the wall, instead of using wood as in the exterior panels (Fig. 42). Such lattice work would not find great favor with the particular housewife because of the tedious work of dusting.

Wood paneling will also break up large areas of concrete surface and is entirely in keeping with the old half-timbered style of architecture, so familiar to our forefathers. It is impossible to appreciate the pleasing surface which has been obtained on this modest appearing dwelling (Fig. 43), but a slight explanation may help to make clear how the effect is obtained. The finish is known as a dry dash and in this instance has been applied to concrete blocks. After the plaster coat has been placed, a dash mixture of white marble and blue stone chips with gravel screenings is thrown on, which

imbed in the mortar and furnish a clean, bright surface without further treatment. When a coarser effect is desired it can be obtained by a rough cast, the mortar mixture being thrown on with a paddle and the texture of the surface depending entirely upon the size and character of the aggregate and the consistency of the mixture.

Stucco finish has found favor when applied to concrete blocks as a backing, and there are some architects who believe that this is the only satisfactory means of handling what has seemed to be in



Fig. 43.—Residence, Jamaica Estate, L. I.

many cases a sad makeshift so far as a building material having architectural merit is concerned. This impression has probably grown from the continued manufacture of rock-faced and inferior blocks by those who are entirely unqualified to undertake this kind of work. Such examples as the Normal Park Methodist Church in Chicago (Fig. 44), the blocks for which were built by the Ameri-

can Hydraulic Stone Company, and the design executed by H. B. Wheelock, has done much to eliminate this impression. The tone contrast was here obtained entirely by the use of colored aggregates, using the natural sand finish on the trim but a dark granite for the body. The surfaces were then scrubbed to expose the aggregate and the building is itself a strong recommendation for the much maligned concrete block.

The residence of E. S. Harkness, at New London, Conn. (Fig. 45), is also of the same kind of blocks and depends for its merit not only upon a design appreciative of the value of the ma-



Fig. 44.—Concrete Blocks in the Construction of the Normal Park Methodist Church, Chicago.

terial but also upon the care in laying up the walls. Concrete blocks are not confined to exterior use, by any means, however, as is illustrated by the work of Emerson & Norris, on the interior of the Second National Bank Building in Boston (Fig. 46). A combination of a tooled surface with careful laying and a little introduction of cast stone work has made the interior of this structure not only dignified, but thoroughly cool and reposeful.

Oswald Hering says that the so-called dry process concrete block is not of concrete at all. Having had little acquaintance with water during its process of manufacture, it consequently harbors an



Fig. 45.—Residence of E. S. Harkness, New London, Conn., Built of Concrete Blocks.



Fig. 47.—Kingsbury Apartments, St. Louis, Mo.

unquenchable thirst and when used in the outside walls of a building, proceeds to make up for lost time, every rain-storm furnishing the elements of a "spree" to the detriment of the block and the appearance of the dwelling. The dry process, however, is not necessary, it being equally as easy to add enough water to insure excellent concrete. The possibility of careful inspection during its manufacture is a strong point in favor of the continued use of this really excellent building material.



Fig. 48.—Detail of Concrete Trim on Kingsbury Apartment Building, St. Louis, Mo.

After considering the all-concrete buildings and the buildings in which other material has been used for ornamentation, it is interesting to turn to work where the latter condition has been reversed and is well illustrated by the work of S. T. Yourtee on the Kingsbury Apartments in St. Louis (Fig. 47). The blocks were cast in sand molds, and on account of the surface given by this

method, subsequent treatment was unnecessary because of the peculiar matte surface which the rough sand mold provides (Fig. 48). Very intricate figures are easily worked out by this process and many buildings in St. Louis attest to Mr. Yourtee's skill in handling concrete.

Another prominent figure in the manufacture of decorative concrete stone is the Economy Concrete Company of New Haven, Conn., which has begun at home to demonstrate the possibilities of concrete for furnishing the ornamentation for buildings of other material. Some of the most interesting work which this company has done, and that which it prizes most highly because of the personal interest, can be seen by all those who visit the home office.



Fig. 49.—Fireplace Detail, Economy Concrete Co., New Haven, Conn.

where the fireplace is composed principally of ornamental concrete stone (Fig. 49). The figures above the mantel are molded after the various workmen about the plant, with the exception of the one at the far right, who represents transportation. The other figures represent in their order (1) the draftsman laying out the plan, (2) the sculptor working over the pattern, (3) the laborer pouring the concrete, and (4) the workman putting the finishing touches on the surface and correcting any flaws caused by removing the forms.

The work is all cast in solid and uniformly proportioned concrete without special surfacing, using wooden or plaster molds. Where necessary, glue molds are employed for the under-cut work. This, of course, gives a rather smooth surface and is the only criticism

which could be made of the product. With but slight additional expense, however, the surface can be chiseled so as to relieve what sometimes appears to be a rather putty-like surface when fresh from the molds.

The work of this company has favorably impressed such architects as Cram, Goodhue & Ferguson, who designed a number of buildings at West Point, including the gymnasium and cadet barracks (Fig. 50). In these structures all the stone work above the first story has been cast by the Economy Concrete Stone Company. The close scrutiny which the government gives the building materials it uses is well recognized and the use of concrete stone in so important structures is a strong recommendation for the material.



Fig. 50.—Gymnasium, U. S. Military Academy, West Point. All Trim Above the First Story of Concrete Stone.

On the interior, all the stone decoration is of concrete, including appropriate relief panels of athletes at various sports (Fig. 51).

The chapel at St. Paul's Church at New Haven, Conn., has furnished another opportunity for this company to demonstrate the superiority of its product, as concrete stone has been used for decorating the old granite structure over 75 years old (Fig. 52). Just lately, the opportunity presented itself to brighten up the old building with concrete, and how satisfactory has been the result is self-evident.

It should make no difference whether the stone trimming is artificial or natural, the end achieved is that upon which we should



Fig. 51.—Interior of Gymnasium, U. S. Military Academy, West Point.



Fig. 52.—Chapel of St. Paul's Church, New Haven, Conn. Window Tracery of Concrete Stone.

pass judgment. In reality, it matters not whether the aggregate in the concrete has been bonded by nature, or by the hand of man with Portland cement as the binding material. So far as permanence is concerned, concrete has already proved beyond a doubt its superiority to many of the natural stones.

St. John's Church is built of a local trap rock which is of a natural gray surface (Fig. 53). But mingled in through the walls are many stones which are rusted, giving a weathered effect, which unobtrusively accentuates the concrete ornamentation, carried even through the tracery of the windows and the tower, and is much in evidence on the interior.

Another instance of concrete applied to ecclesiastical architecture is found in the Broadway Presbyterian Church of New York



Fig. 53.—St. John's Church, Hartford, Conn. All Trim and Tracery of Concrete Stone.

City (Fig. 54). The natural stone walls of the building are of New York gneiss laid up in random ashlar, and all the trimming, including the window tracery, is of concrete stone. This was cast in sand molds by the Onondaga Litholite Company of Syracuse. The aggregate used for manufacturing this particular stone is made from Gouverneur marble, a hard calcite product from northern New York. This flinty material in crushing, breaks into sharp angular pieces, which are graded into several sizes, depending upon what work they are to enter. After removal from the sand molds, the concrete is carefully cured and then tooled and surfaced by machinery. The surface obtained is identical with natural stone—but oftentimes is superior to it, because of its greater ability to resist the action of the elements. Conclusive evidence of this character-

istic is to be found in the old sandstone decoration on the Königsbau at Stuttgart, erected about 30 to 50 years ago. The upper cornice was ornamented by a number of large figures which began to disintegrate, making replacement of some of the parts necessary from time to time. As a final remedy, the officials proposed duplicating the figures in concrete. This decision was arrived at after inspecting several artificial stone figures which had shown practically



Fig. 54.—Broadway Presbyterian Church, New York City.

no deterioration after 20 years of exposure to the elements. The surface of the new figures was tooled after coming from the forms so that they were identical in texture with the discarded sandstone models.

The Universal Portland Cement Company attempted something unusual in the construction of its new office building at Buffington,

Ind. (Fig. 55). The building is of plain faced concrete blocks with the monotony broken up by the insertion of smaller squares and bands. The surface is further brightened by a ground surface finish which exposes the limestone aggregate and adds life.

In Boston, an imposing memorial showing tooled surface has been erected in Post Office Square (Fig. 56). This pleasing combination of cast stone with monolithic concrete was erected by Emerson & Norris and designed by Messrs. Peabody & Stearns, all of Boston. The monument is supported on reinforced concrete piles and the central portion is faced with cast stone, but the shaft was cast in place and afterward bush hammered to match the ornamentation. For aggregate, a mixture of granite, white and black marble, was used, which when exposed gives a sparkling and contrasty surface, displaying the combined characteristics of the individual materials.

The writers, not being architects, have dealt somewhat sparingly



Fig. 55.—Office Buildings, Universal Portland Cement Co., Buffington, Ind.

with the subject of architectural and decorative possibilities of concrete and have rather depended upon the illustrations to indicate the purpose of this paper. After all, architecture and architectural decoration is a peculiar study. On the one hand, we have those who contend for close adherence to the ancient styles of architecture, and on the other hand, we have many brilliant minds who have achieved wonderful results and designed some of our most pretentious structures along entirely new lines, yet without voluminous criticism from those who consider themselves authorities. However, since this paper has dealt more particularly with the architectural side of concrete, it is, perhaps, fitting that we close with a quotation from Oswald Hering, who has made a study of concrete and its architectural and decorative possibilities, and who, by the way, is a son of Rudolph Hering, an honored member of the Western Society of Engineers:

"Concrete can be easily and rapidly manipulated. It is less expensive than either clothed steel or masonry construction alone; it does not deteriorate with time and it is practically fire and waterproof. It grows in strength for a con-



Fig. 56.—Angell Memorial, Post Office Square, Boston.

siderable length of time and after having attained its ultimate strength, it never weakens, consequently, by its use, lighter, cheaper and more durable structures may be erected than with any other known materials."

Regarding concrete stone he says:

"The time would seem to be not far distant when concrete will very largely supplant marble and stone where castings are practical. These should not be termed 'imitations' of stone, for the ingredients are largely the same as are found in real stone. Nature's process of employing time and gravity has simply been superseded and accelerated by man's mechanical ingenuity."

DISCUSSION.

President Reichmann: We have had the pleasure of listening to a very interesting paper this evening. Perhaps Mr. Boynton would like to start the discussion.

Mr. Boynton: We found many points of interest, in preparing this paper. The work of the Economy Concrete Stone Company is of particular interest because they have developed a type that they insist on making one way; if the architect likes it he can use it, if not, he can leave it alone. I think that is one reason why they have succeeded so well in getting a product that is uniform and really desired by the architect because it is dependable.

The Economy Concrete Stone Company cast their product in the different molds necessary to get the lines desired and then rub the product with rubbing stone, carborundum, or whatever is necessary to expose the aggregate product. When I last visited their plant they had a large piece that they were casting for a Government hotel at Panama. The Government holds this company in high esteem, because of the quality of the stone they are producing.

The work that the Emerson & Norris Company are doing is wonderful in that they have practically displaced building stone for entrance decoration in Boston. There are block after block of apartments in which all the entrance work and all the stone trim from the ground up to the window-sill, on the first floor, is cast stone or concrete stone rather than natural stone. Natural stone is no longer "in the running" where other stone can be obtained, because the latter is more uniform; it is more economical, because it can be cast in practically the shape and form required and thus reduce the cost of cutting to a minimum. This does not mean that it is sold cheaper because it is less attractive or less desirable (it is really more attractive and more desirable), but being influenced by the cost of the product it results in economy.

The Germans have been replacing with concrete, for twenty years or more, all the old stone work that has deteriorated. The stone work referred to as being now replaced with concrete was mentioned last December at the annual meeting of the National Association of Cement Users. A gentleman from Germany was in this country at the time, who had some lantern slides showing work in which they were replacing figures on the top of some of the German Government buildings. Some of the pictures showed where they

were replacing with concrete the old sections of heavy stone columns which had deteriorated, retaining the form and texture and color. He said it was not at all uncommon to do that.

Q. Where cutting of the cast stone is necessary, can as delicate work be done as on the natural stone, or is there a tendency of the material to spall or crumble under the chisel?

Mr. Boynton: I believe good concrete will not spall as readily as natural hard stone. You doubtless have noticed some effects of concrete blocks (for instance, such as Mr. Hering referred to) where sufficient water had not been used in mixing the concrete, and where the blocks had been improperly cured, etc. That results in a crumbly product and chiseling is impracticable. In fact, the ends could be rubbed off with the finger. But a well-made concrete product can be worked in a manner similar to that of good building stone. The way it will cut will depend somewhat on the age and the size of the aggregate. If made of large aggregate it would require more time, so as to resist the tendency to break through the aggregate at a point not broken by the chisel, but after it is properly aged the size of aggregate makes no difference. If a product were to be chiseled it would naturally be made of finer aggregate; that is, $\frac{1}{4}$ to $\frac{1}{2}$ in. rather than $1\frac{1}{2}$ in. stone. There is no danger of properly-made concrete spalling or crumbling after it has reasonable or proper aging.

President Reichmann: About how old must concrete be before it can be worked with a chisel?

Mr. Boynton: If necessary, and the concrete were cured under steam, it could be chiseled in a week's time, if made with that in view; but under ordinary circumstances with normal aging under normal temperature and with water only, I think it could be chiseled safely in thirty days.

Q. I would like some information as to how the ornamental tiles are applied. Are they placed in the forms before the concrete is poured, or, if not, are blanks for them provided, and the tiles subsequently inlaid? Also, is any material or backing or mechanical bond for them necessary?

Mr. Boynton: It is usually the practice to put a blank in the form, outlining in a general way the shape of the figure or the tile that is to be set in, having the blank the same depth as the piece to be set plus a light mortar backing. Then with careful setting, thorough moistening of the concrete, and careful placing of the tile in the proper mortar, it adheres firmly.

Q. What material was used in stenciling the interior of the building that represented the lattice? Was it paint?

Mr. Boynton: I presume it was. There are a number of formulæ that will produce good paint for painting on concrete, even on green concrete. Any form of linseed oil paint can be used, if the concrete is thoroughly aged. But we never know exactly when it reaches that point and we are apt to want to decorate the surface

before that time. With the use of the proper formula it is perfectly safe to paint concrete as soon as it ordinarily dries out, say in thirty days' time.

Q. Must the paint be something special?

Mr. Boynton: Yes, but it is an inexpensive paint. Linseed oil on concrete may prove troublesome and have to be removed.

Mr. Stineman: The statement is made in the paper that pleasing architectural effects may be made in concrete with very little or no additional cost. That is something which engineers should bear in mind, because many of them are inclined to the belief that anything which looks well will cost too much. As a result they erect buildings which are nothing but walls with holes in them, and bridges and structures that are unsightly from an architectural standpoint. They say, "We will put up the structure so it will hold and do the work, and never mind how it looks." Yet with the same or a little more money a pleasing architectural effect might be had. I notice among the illustrations several viaducts in this city, plain in surface or plain in line, which have a pleasing effect because some architect or some man who understood architecture designed them. I would not go so far as to say that engineers should be architects or should make a study of architecture, but I believe engineers should either learn something about architecture or else, in the case of structures which are built in places where people must look at them for years and years, engage an architect to design for them, if they are not able to do it themselves.

President Reichmann: I think that is a very good point. It is only within the last few years that engineers have ceased using most of their time developing new theories for the engineering profession. We are now spending a little more time developing architectural effects of our designs. Years ago, any attempt in the line of aesthetic design in connection with factories was immediately cut short; the owner would not allow the engineer to put anything on the structure in the way of ornamentation, because it would cost a few dollars. But we are now approaching the time when there is more willingness to give the structure attention from an aesthetic standpoint. I believe the engineer is capable of doing this, but heretofore he has not been permitted to do it. There is a great difference in the factory of today and the one built twenty years ago. At the present time, the light and the general features are thoroughly considered before the work of planning is started.

Mr. Boynton: Regarding the work of Mr. Squires in New York, there is one point I might mention as to getting the decorated ceiling effect by using inverted sand molds for the forms. We tried to secure a photograph of the finished ceiling, but had to give up the idea after making several efforts, because of the difficulty in getting back far enough and securing the proper lighting.

In that work Mr. Squires has gone a step forward, I think, in that he will get all the strength he requires through the beams be-

tween the decorations. He will also do away with the plain ceiling at a cost that will be taken care of by the cost of a plain ceiling. He says the cost of building such a ceiling is practically nothing, over the plain ceiling. He saves weight with his structure—saves all the way down the line—and he has a decoration when he gets through that is attractive. Those things are well worth our consideration, and doubtless many of us in our every-day work will see how by study we can get some decoration or pleasing effect without adding materially to the cost; possibly decreasing the cost. Mr. Squires is an architect and not an engineer; that is, he is practicing as an architect, and his work has been confined very largely to residences and apartments. But the same principle can be used in other buildings where a decorated ceiling is desired or there is any desire or need for breaking up the monotony of a ceiling. The cost of such work will doubtless be a little more until we become accustomed to it, or until we have men trained to making the blanks.

One thing that has kept us back and interfered with the proper development of concrete, is that the man who makes the initial expense must necessarily be at more expense than the one who comes after him. We find this in building houses. For instance, in building houses at Gary, the first year's houses cost much more than the second year's work. The saving the second year was astonishing, and it was due to the fact that a trained organization had been developed the second year, avoiding delays and in many ways effecting savings.

The point we have tried to bring out in the paper is that in concrete we have a material from which we can get results. The only real lesson we have tried to teach is that in concrete there are great possibilities for beauty, and this beauty can be brought out by giving a little thought and study to the matter.

CHICAGO WATER WORKS

JOHN ERICSON, M. W. S. E.

Presented May 19, 1913.

The purpose of this paper is primarily to bring to the attention of the members of this Society and to the public the high and steadily increasing per capita consumption of water in this city, and if possible to bring those particularly interested and the general public to a realization of the necessity for accepting and carrying into effect a policy that will speedily bring about a change and which will conform to methods which have long since been adopted in European and in several progressive American cities.

The past history of Chicago's water supply system has been written up on several occasions, but, in order to bring this history up to date, as well as to more clearly bring out various conditions, the author finds it advisable to again touch upon, in a general way, the past development of the system.

INTRODUCTORY.

As long as earthly life has existed both the animal and the vegetable kingdoms have depended for their existence on an adequate and suitable water supply. The lonely settler, whose cabin was located by the everlasting spring or brook, had no necessity for any mechanical device for the collection or storage of the commodity. In fact, ancient legends and writings indicate that man first imitated the animals. Many savage tribes quench their thirst to this day by lying down.

Mr. Humber in his "Water Supply for Towns and Cities" says: "Ovid describes Latona on a journey. Languishing with thirst, she arrives at a brook,

And kneeling on the brink

Stooped at the fresh repast, prepared to drink."

As the race increased and people commenced to live in communities, the earliest method of artificially obtaining and storing a water supply was by the digging of wells. Wells undoubtedly are of antediluvian origin, and the knowledge of them, like that of the primitive arts, has been preserved by an uninterrupted use from the period of their first discovery. At first they were probably nothing more than shallow cavities dug in moist places, and their depth accordingly increased in order to contain water that might drain into them within certain intervals of time.

One of the ancient proverbs of the Chinese is: "Dig a well before you are thirsty," and the many deep artesian wells found in their country give evidence of their proverb having been duly regarded.

As communities grew larger, water was collected in reservoirs and conducted through conduits and aqueducts, sometimes long distances, to the place of consumption. One of the earliest aque-

ducts of history was that of which vast remains may be seen to this day, ranging for miles over the plains near the site of ancient Carthage. Among other ancient constructions of this kind was the Appia Claudia, partly aqueduct, partly tunnel, supplying water to the city of Rome. It was built in the year B. C. 322.

The storing of water in large quantities probably had its origin among the Egyptians, who were also distinguished for the contrivances for raising water from the river into elevated reservoirs. In those early days, even the city people were satisfied to have the water brought to cisterns within their community, where they could secure the commodity in carts or buckets and thus carry it or have it delivered to their homes.

Contrivances in various forms for the raising of water have been known since time immemorial. The archimedian screw was one of the very early devices used for this purpose, and the same principle has in late years been applied in the development of the modern centrifugal and screw pumps. The water ram and reciprocating pumps were later developments, the former being used extensively for private supplies and the latter being used all over the world for delivering water under high pressure. The machinery for raising water is worked by the power of animals, man, wind, water, steam, gas, or electricity.

The development of modern water works in Europe was slow up to the eighteenth and nineteenth centuries and was confined principally to London and Paris. In the United States the progress in the development of such works, especially in the improvements in the making of cast iron pipes and the perfection of pumping machinery, has been marked since 1850. Today there is not a city and hardly a village that has reached a population of a thousand inhabitants that has not its own water supply system.

With the application of steam to the pumping of water and the introduction of pipes able to withstand pressures, a great impetus was given to the development of water works. Water could then be delivered direct into the houses ready for use at all times. In late years electricity is more or less supplanting steam as a source of power, but for reliability in constant service and economy of operation steam is still holding its own.

EARLIEST DEVELOPMENTS.

The struggling little group of settlers on the banks of the Chicago River and on the shores of Lake Michigan at and near the mouth of the River had in 1833 reached the number of 350. Some kind of government became necessary, and the town of Chicago was incorporated. Four years later the population and the activity had increased sufficiently to require a change in the form of government, and the city of Chicago was incorporated in 1837.

In those early days this little group of citizens located on the shores of one of the largest natural fresh-water reservoirs in the

world, and not being used to the luxury of having the water supply delivered by gravity or machinery through pipes into their homes, gave but little thought to the development of water works, securing their supply in buckets and barrels, as it was needed, from lake, river or wells. Some enterprising fellows reaped a harvest by carting and selling the water to the districts that were lying more remote from the natural reservoir.

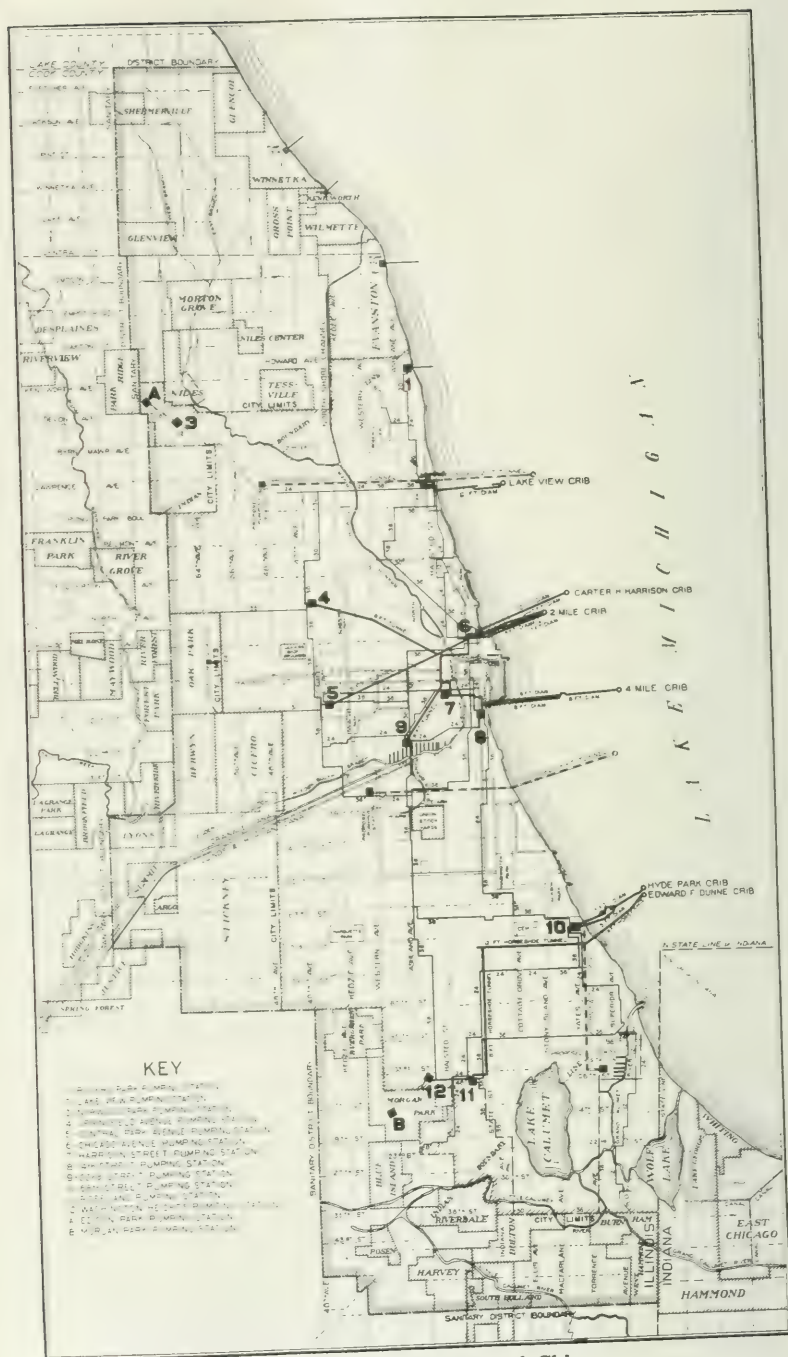
In 1836 a few progressive persons formed a company called the Chicago Hydraulic Company, which was granted a franchise to build water works and to supply water to the citizens.

It was not until 1840, however, that any real attempt to construct a water supply system was made, and the first work in this direction was the construction of an elevated reservoir at Lake Street and Michigan Avenue, the installation of a 25 h. p. pumping engine, and the laying of about two miles of logs with holes bored through their centers, which served the purpose of water mains. The supply of water to the pump was obtained through an iron pipe which extended out into the lake a distance of 150 ft. The young city grew rapidly, and the services rendered by the private water company became more and more unsatisfactory by failure on its part to keep the water works improvements apace with the increase in population and demand for water.

CITY OWNERSHIP.

In 1851, the city having by this time reached a population of about 30,000, was given, by legislative act, the power to establish its own water works, and the franchise of the Chicago Hydraulic Company was taken over by the city. From this time on a new era in the development of the water supply system of Chicago was initiated. Work on a new plant was commenced immediately with the construction of a pumping station at the foot of Chicago Avenue near the Lake. A pumping engine with a capacity of 8,000,000 gallons per day was erected and supplied with water through a pipe 30 in. in diameter, reaching about 600 ft. out into the Lake and terminating with a submerged timber crib. The water was pumped into and distributed through three reservoirs erected respectively at La Salle and Adams Streets, Chicago Avenue and Sedgwick Street, and Morgan and Monroe Streets. The first ones were built in 1853 and the latter in 1854. The capacity of each was sufficient for two or three days' supply.

Now also commenced an era of annexations of territory to the city, and the rapid increase in area, as well as in population, required extensions to the water works system that taxed the resources of the city to the utmost. In 1856 it became necessary to erect a second pumping engine at this station, and one with a capacity of 13,000,000 gallons daily was installed. In 1858 two new reservoirs each of 500,000 gallons capacity were erected in the west division, one on Sangamon Street near Monroe Street and the other on Chicago Avenue near Franklin Street.



The Water Works System of Chicago.

The two pumping engines above described were in service until about ten years ago.

In 1863, or just 50 years ago, the city was still further enlarged by the addition of several square miles of territory. Chicago had now grown to be a city of about 150,000 inhabitants. Its people were supplied with water by means of the two pumping engines and four boilers located in the station at Chicago Avenue and the Lake. The total capacity of the plant was now 21,000,000 gallons per 24 hours, and the average daily pumpage was at the rate of about 6,400,000 gallons. The water was distributed through about 120 miles of water mains with which 548 fire hydrants were connected. The area of the city at this time was about 24 square miles, and the daily average consumption of water per capita was then only 43 gallons.

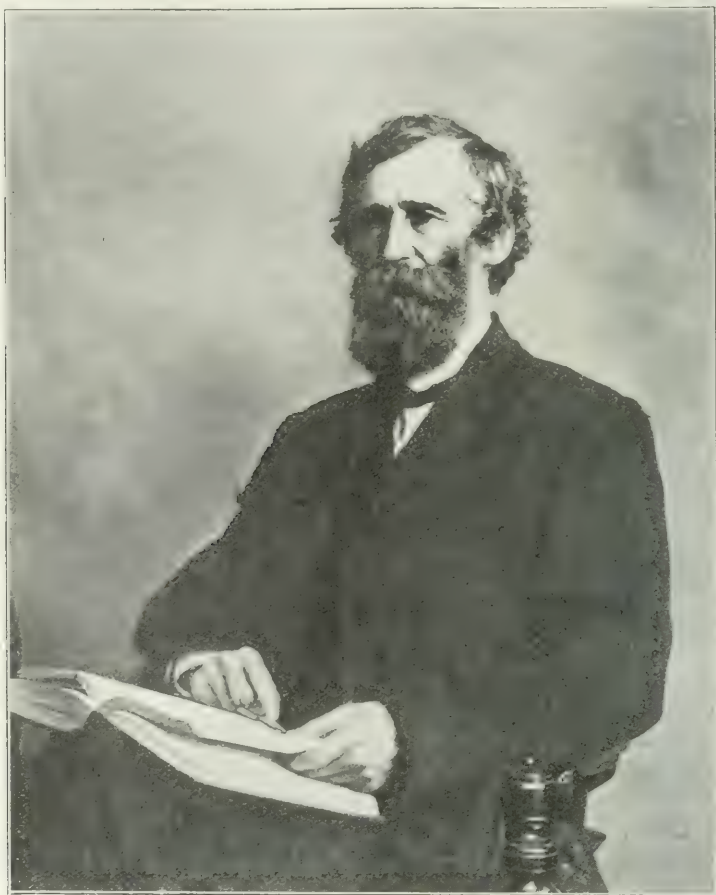
SANITARY CONDITIONS OF WATER SUPPLY.

While the capacity of the new pumping station with the low per capita consumption was more than ample for some years, the rapid increase in population of the city, its increasing commerce and trade, and the construction of miles of sewers which discharged their foul contents into the waters of the Lake and River brought about a condition as regards purity of the water supply that soon became well nigh unbearable and made Chicago a butt for jokes all over the country. The Chicago River, ordinarily more like a currentless bayou, became a cesspool of filth, which the spring floods carried out into the Lake, contaminating its water for a considerable area and rendering the water supply extremely impure. Small fish that sought the shallow water near the shore were drawn into the water intake pipe and after passing through the pumps were disseminated through the water pipes of the city.

Owing to the War, which absorbed the attention of engineers and others all over the country, this state of affairs was endured until 1863, when the limit of endurance was reached, and the citizens began to show a determination to have the conditions changed. Many schemes for purifying the Chicago River were proposed, all more or less extreme and impracticable. Even at that early date the suggestion to construct a series of intercepting sewers was made, but the expense and the time required would be so great and the entire matter so much of an experiment that the scheme was abandoned. The ship canal idea, with a view of reversing the direction of flow of the River, as is now the case since the completion of the Drainage Canal, was also under consideration, but a bill introduced in Congress for this purpose was killed and deprived the citizens of all hope of relief in that manner.

With an inexhaustible reservoir of pure water located at their very door, requiring only some means whereby the crystal fluid could be brought from a sufficient distance from shore, the authorities were bordering on a state of desperation. The idea of constructing a tunnel under the bed of the Lake was now brought forward, but was declared impractical by many engineers.

To the forethought, skill, and determination of E. S. Chesbrough, the City Engineer at that time, is due the adoption and consummation of this idea of securing for the coming metropolis an improved water supply, which method has since added so much to the growth, health, and prosperity of this city, and made later problems of extensions as regards methods comparatively easy, both for



E. S. Chesbrough.

Chicago and other Lake cities that later profited by Chicago's experience.

THE FIRST LAKE TUNNEL.

The first Lake tunnel, 5 ft. in internal diameter, built of brick and extending two miles out under the Lake, was now inaugurated with appropriate ceremonies, and completed in 1867. This first



Exterior View—Edward F. Dunne Crib

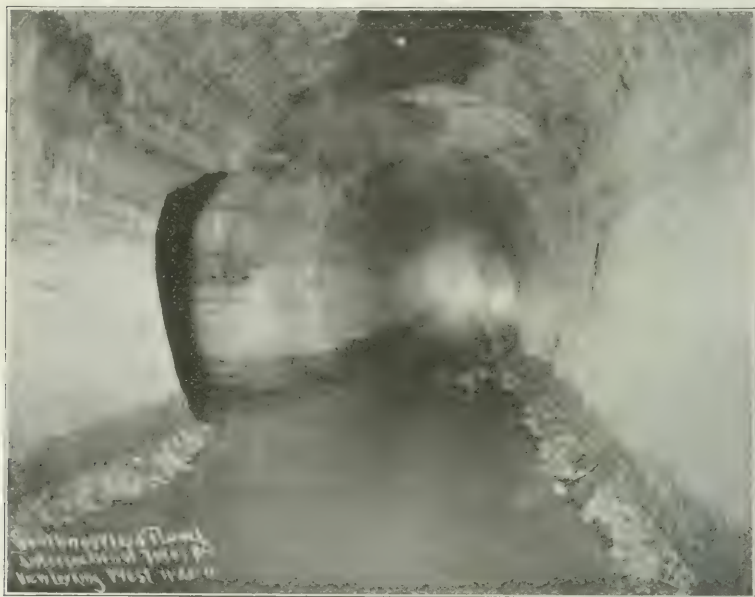


Interior View—Edward F. Dunne Crib.

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water tunnel, during its construction, was visited by state and government officials and many other prominent people and by engineers from both this and other countries.

The tunnel terminates with a vertical shaft or cylinder extending up above the bottom and surface of the Lake, and through which the Lake water enters the tunnel. To protect this intake cylinder from storms and vessels it was necessary to build a substantial structure around it. This structure, the so-called Chicago Avenue Crib, built of granite and limestone laid in cement mortar on a stone-filled timber crib foundation, was sunk in place northeast from the pumping station and remains in service to this day.



Southwest Land Tunnel—Intersection at Yates Ave.

In addition to taking the water from a point far out in the Lake, means were adopted for reducing the amount of sewage discharged into the Lake by the River. The first step in this direction was the deepening of the Illinois and Michigan Canal so as to cause a flow by gravity from the River at Bridgeport towards the Desplaines River. This proving insufficient, pumping works were established at Bridgeport, which continued in operation until the opening of the Drainage Canal. The effect of the pumping was never at any time more than a partial improvement of the conditions.

The increase in the area of the city of Chicago through one annexation after another of adjoining territory and the rapid increase

in population has brought up one new problem after another as regards its water supply.

The first pumping station located at the Lake on the eastern margin of the city was gradually demolished in 1864, and the erec-



8-ft. Sluice Gate—Blue Island Ave. Land Tunnel.

tion of a new and more commodious building, part of the Chicago Avenue pumping station of today, was completed on the site. This building and tower were finished in 1869. This station could not deliver sufficient water at the required pressure to distant inland

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portions of the city, owing to the frictional losses in the long pipes, and it became apparent that another pumping station, more centrally situated, must be constructed so as to provide an effective service to those districts.

The successful completion and operation of the first tunnel, referred to, solved the engineering problem of delivering pure water by gravity to the wells of a pumping station, no matter where located. If funds were available the construction of tunnels of any length could now be undertaken without serious apprehension as to the success of such a venture.



Exterior View—22nd Street Pumping Station.

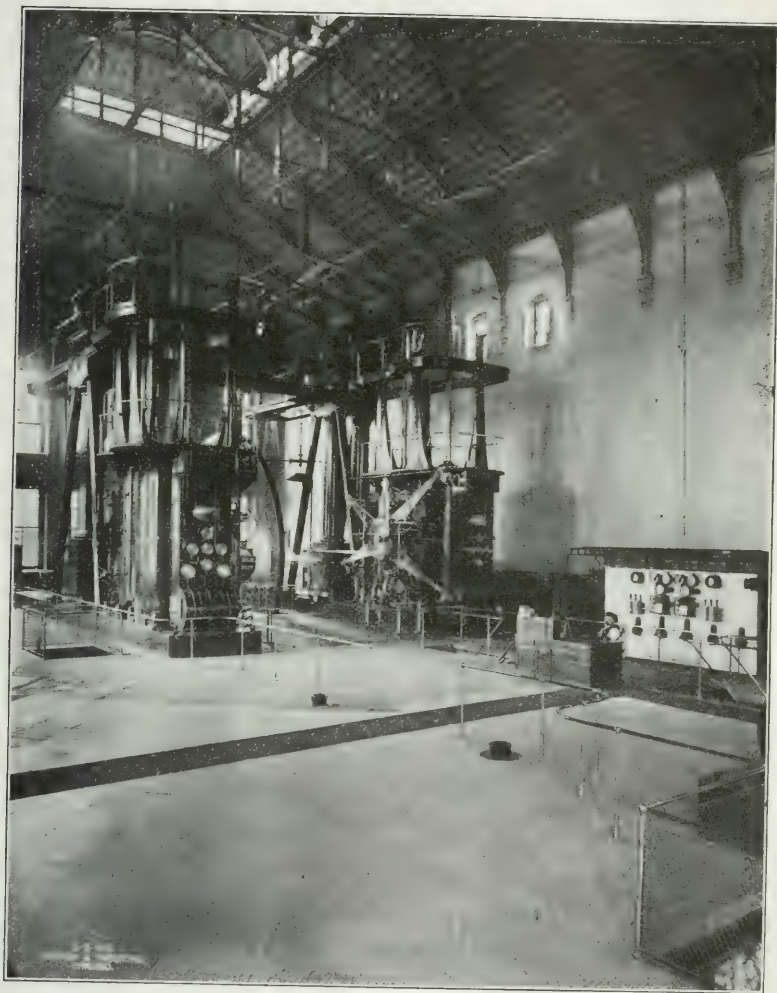
EXTENSION POLICY.

A second pumping station, located inland on Ashland Avenue near 22nd Street, four miles southwest of the Chicago Avenue station, was now planned. In order to lead the Lake water to the proposed pumps at this station, work on a second tunnel, 7 ft. in internal diameter, extending in a southwesterly direction from the original crib, paralleling the first tunnel to the Chicago Avenue pumping station and thence diagonally across the city to the new Ashland Avenue station, was then commenced.

This new station was constructed and the first installation, consisting of two new vertical compound pumping engines with a daily capacity of 15,000,000 gallons each, was erected, the entire system

being completed in 1876. In the meantime, an additional pumping engine of 36,000,000 gallons capacity had been installed at the new Chicago Avenue station.

Thus, the second important step in the development of the water



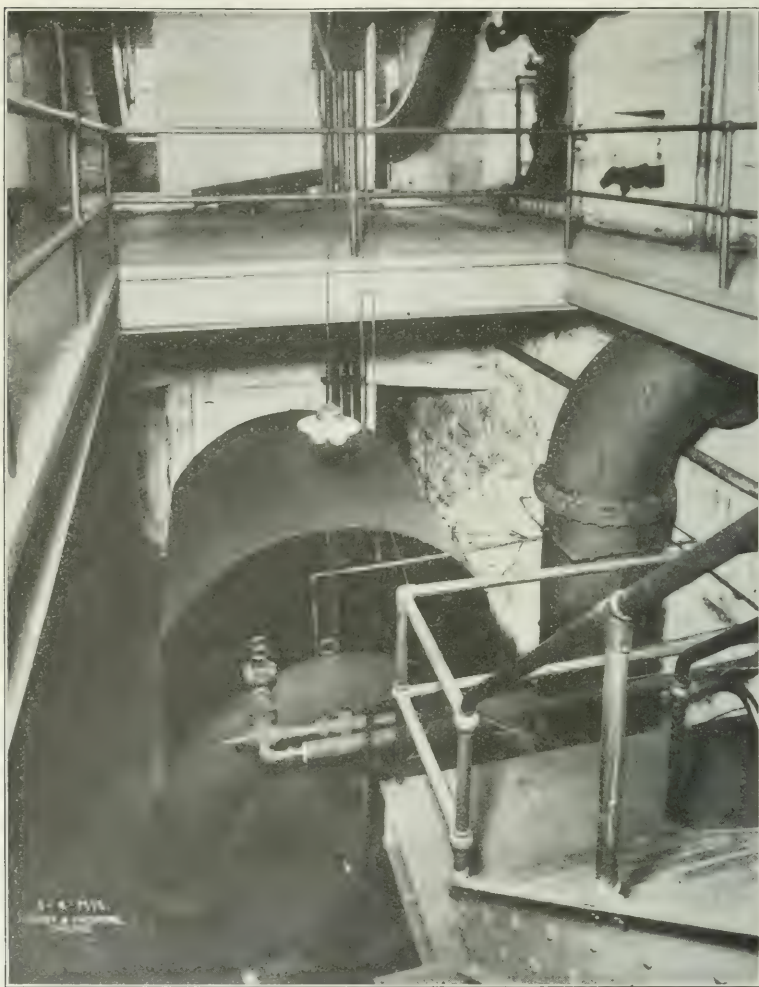
Interior View—22nd Street Pumping Station.

supply system of Chicago had been conceived and successfully executed.

These two pumping stations, with some additional pumping engines, served the city for about a decade, when the limit of tunnel October, 1913

capacity had been reached and it became apparent that new tunnels and additional pumping stations must be constructed.

A new system, embracing one pumping station, located at Harrison and Desplaines Streets, with two 15,000,000 gallon pumping



Electrically Driven Centrifugal Pump—22nd Street Pumping Station.

engines, and another pumping station, located at 14th Street and Indiana Avenue near the Lake Shore, with three 15,000,000 gallon pumping engines, was now planned. An entirely new tunnel system supplying these stations and extending four miles out under the

Lake, terminating at the so-called Four Mile Crib off 12th Street, was commenced in 1887 and completed in 1891. An additional 30,000,000 gallon pump was installed a few years later in the 14th Street Station.

In 1889 several adjoining towns, namely, Lake View, Jefferson, Hyde Park, and Lake, each with its water supply system, were annexed to the city of Chicago, adding in one year 126 square miles to the city. None of the annexed systems, of course, formed any part of the Chicago system, but were entirely detached and independent of each other and of the Chicago system.

Each annexed system, with its station located on the Lake Shore on the eastern margin of the city, was more or less inadequate and run down and needed immediate improvements and extensions. Some scheme for the unification of these various systems into one whole also became a necessity. The original city of Chicago had laid only such pipes as were necessary for its present and immediate future use. Each one of the annexed towns had planned in the same way. The water was in some cases taken near the shore through iron pipes. Each system had been added to gradually, as necessity required, without much thought being given to future expansions and none to a possible amalgamation of the various systems. Instead of one intelligently planned and developed system, the city now had on its hands a number of these independent systems, each more or less inadequate even for the district it was designed to serve. New pumping stations with modern machinery and new tunnels to supply these stations with pure water were planned almost immediately for the annexed territories.

In 1890 the Washington Heights district and in 1893 Norwood Park were added, both of which had to be given immediate attention in the way of water works improvements. Other territory was added to the western and northern part of the city, namely, Austin and Rogers Park, respectively. Each part of the greater Chicago grew rapidly in population and manufacturing establishments. The problem of making these detached systems into one efficient whole and at the same time providing for the constantly required increases greatly taxed the capacity of the City Engineer, who had many other duties.

Owing to the great increase in population, pollution of the Lake water became more and more distressing. The length to which Lake tunnels can be built is limited by cost and the increasing depth of water at greater distances from shore. Some means of preserving the purity of the water supply within tunnel limits became again necessary. This resulted in the construction of the great Drainage Canal, principally for the purpose of reversing the direction of the flow in the Chicago River, and the construction of intercepting sewers to divert the discharge of sewage from the Lake and River to the Drainage Canal, thus minimizing the principal cause of pollution of the water supply.

The cost of these works, as far as executed, is about \$70,000,-000, exclusive of the cost of the water supply system proper.

Hardly had the last extensive system of tunnels and pumping stations been completed before another one had to be planned.

A system embracing the Central Park Avenue and the Springfield Avenue pumping stations located far inland, each designed for an ultimate tunnel capacity of 100,000,000 gallons, and including the large tunnels, terminating at the Carter H. Harrison Crib (located about three miles from shore) and extending in two branches inland



Exterior View—Springfield Ave. Pumping Station.

to the pumping stations, was commenced in 1895 and put in operation in 1900 and 1901.

LARGE CONNECTING MAINS.

The city now had eleven pumping stations widely separated.

In order to obtain as elastic a system as possible, so that in case of necessity the plant in one district could assist those in other districts, it became necessary to interconnect and reinforce the various systems with large water mains. This work was commenced in

1898, during which year 50 miles of large cast iron pipes 24, 36 and 48 in. in diameter, and at a cost of nearly \$1,500,000, were laid. The work has since been continued until the entire water supply system of Chicago now represents a fairly well connected whole.

As early as 1901 the author made a special study of the water supply situation in the southern part of the city. This location, with its rapidly increasing population, embraced one-half of the city area, and was supplied by only one pumping station located in the northeast corner of this territory at 68th Street and the Lake, about



Exterior View—Central Park Ave. Pumping Station.

nine miles from the southern city limits, necessitating the forcing of the water long distances. This resulted in recommendations for the immediate construction of a new tunnel system for this part of the city and a new pumping station located at Roseland in the vicinity of State and 104th Streets. Not until 1907, however, or six years later, were the city's finances in a condition to permit the beginning of these much-needed improvements.

This new system, besides the pumping station at 104th and State Streets, embraces, so far as completed, about 11 miles of tun-

nels from 9 to 14 ft. in diameter, including two miles under the Lake, and a new Crib. The new pumping station with an initial capacity of 50,000,000 gallons per 24 hours, or one-half of the ultimate capacity, was put into operation in December, 1911. The tunnel has a capacity to supply two more proposed large pumping stations in this territory and to reinforce the 68th Street Station.

BOOSTER STATIONS.

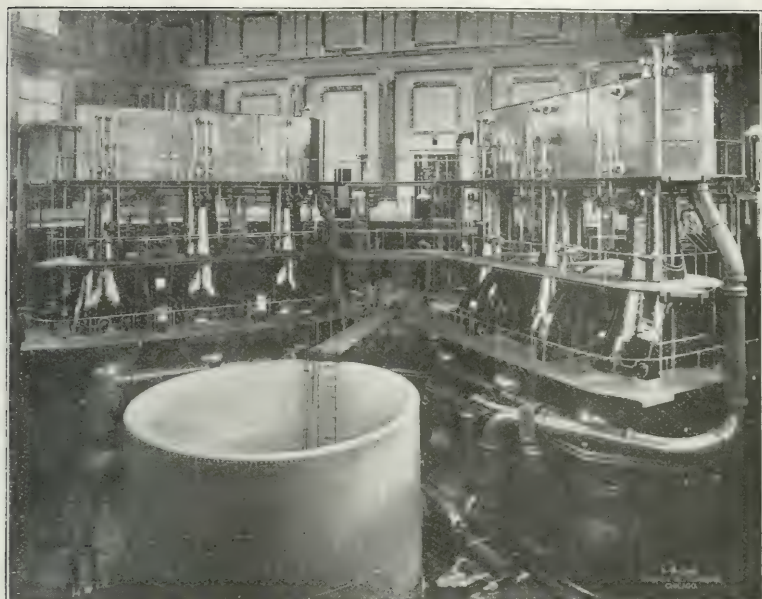
Some territory located at the west, northwest, and some other points in the city has an elevation of from 60 to 70 ft. above Lake level, while the general elevation of the city varies from 10 to 25 ft. To furnish a satisfactory supply of water to these high and distant



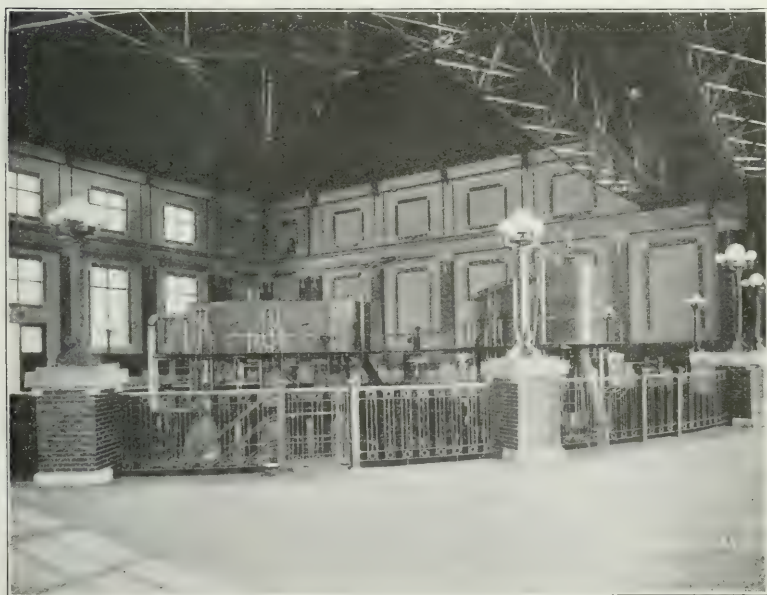
Roseland Pumping Station.

points direct from the city pumping stations would require an unnecessarily high pressure to be carried at the large pumping stations. Some of these outlying districts have been supplied from independent deep well systems at an excessive cost to the city. Partly on this account and partly on account of the insufficiency and hardness of the well supplies, some of these stations have been changed to boost the pressures of the Lake water supply.

A new booster station located at Mayfair on the northwest side was also lately put in operation, supplying Norwood Park, Edison Park, and Mont Clare with Lake water at increased pressures. The suctions of the pumps, which are oil-engine as well as



Interior View—Roseland Pumping Station.



Roseland Pumping Station—Engine Room.

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electrically driven, are connected with the low pressure mains of the general system.

Plans are now being prepared for special high pressure units to be located in some of the large stations to specially serve such



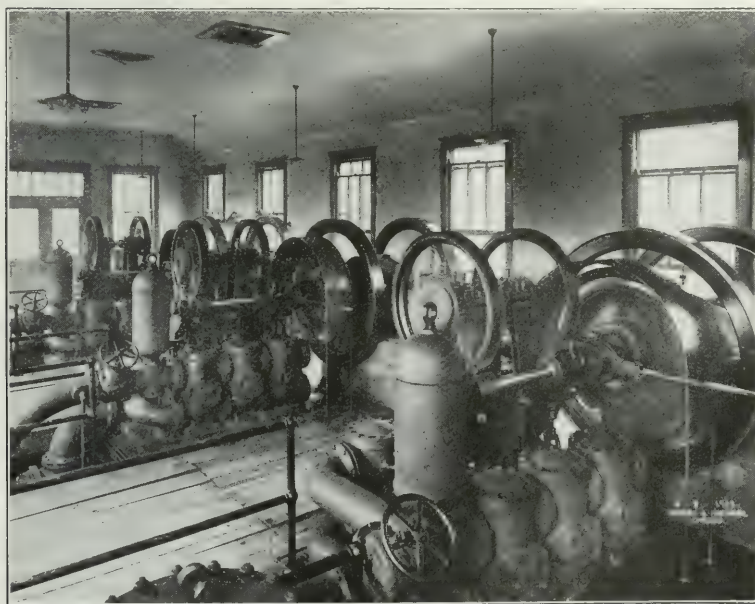
Roseland Pumping Station—Boiler Room.

high districts. The small independent booster stations will then be abandoned.

The water supply system of Chicago January 1, 1913, consisted of the following:



Exterior View—Jefferson Park Pumping Station.



Interior View—Jefferson Park Pumping Station.

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- 9 large pumping stations.
- 5 smaller auxiliary pumping stations.
- 33 large reciprocating steam pumps.
- 7 small reciprocating steam pumps.
- 2 steam turbine driven centrifugal pumps.
- 3 oil engine driven pumps.
- 2 electric motor driven centrifugal pumps.
- 59 steam boilers in nine principal stations.
- 6 steam boilers in minor stations.
- 6 intake cribs.
- 2,425 miles of cast iron pipes from 6 to 48 in. in diameter.
- 25,542 hydrants.
- 21,099 stop valves.
- 271,000 service pipes.
- 16,052 water meters.
- 49.4 miles of water tunnels from 5 to 14 ft. in diameter in service.
- 22 tunnels under River and Canal for water pipes; total length 9705 ft.
- Total nominal pumping capacity of nine principal stations per 24 hours, 723,000,000 gallons.
- Average pumpage per day in 1912, based on plunger displacement, 551,324,000 gallons.
- Maximum pumpage in one day (February 9, 1912), 670,000,000 gallons.
- Average amount delivered daily to mains, deducting slip and water delivered to suburbs, 465,286,000 gallons.
- Average consumption per capita per day, based on actual amount delivered into mains, 203 gallons.
- Cost of entire system to December 31, 1912, \$56,772,431.
- Total area of the city, 191 square miles.

In addition to this enormous plant, there are now under construction:

- 5 large steam pumping engines, and
- 4 steam turbine driven centrifugal pumps to reinforce existing stations.

This will add, before the end of the year, a capacity of 225,000,000 gallons per 24 hours to the system, and still there is more to come.

WATER CONSUMPTION IN CHICAGO.

As stated, the water works of Chicago during the last year pumped a quantity of water which, equally distributed, amounted to 551,000,000 gallons each day, and this pumpage on a certain day reached 670,000,000 gallons, slippage in pumps included. This great quantity of water would fill a tank 100 ft. in diameter and about two miles high every day in the year.

Imagine, if you will, a giant hemispherical dipper 50 ft. in diameter and 25 ft. deep. Such a dipper would have to be filled to

the brim from the Lake 2,700 times to bring to the city a quantity of water as great as was lifted up by the city's water works pumps in one day in 1912.

The total quantity of the pumpage during last year would fill a lake averaging ten miles in length and four miles in width to an average depth of nearly 30 ft. It is equivalent to 203 gallons, or a barrel 3 ft. in diameter and 4 ft. high full of water, for every man, woman, and child in the city every day in the year, if equally distributed. Of course, in these figures is included all the water used by the Stock Yards, manufacturing, and other great water-consuming establishments. And yet we hear a constant cry for more water—more water. To satisfy this enormous thirst of our citizens, the city administrations, which are changed every two or four years, under prevailing conditions, must go on adding one system after another at the cost of millions upon millions of dollars.

The budget for 1913 includes, among other normal additions to the system, provisions for two entirely new pumping stations, one to be located at 49th and Wilson Avenues and another somewhere west of Western Avenue, adjacent to the Drainage Canal, each to have a capacity of at least 100,000,000 gallons per day, and each to be supplied with water through large independent tunnel systems with independent Lake cribs to be located about three miles out in the Lake.

About \$12,000,000 have been set aside this year for these and some other additions to the Chicago water system, for which the City Engineer must supervise the preparation of proper construction plans and see that the construction work proceeds as rapidly as possible.

What, then, becomes of all this water?

DISTRIBUTION OF WATER SUPPLY.

Careful investigations by the Water Survey Division of the Bureau of Engineering show that the water actually delivered into the mains is distributed about as follows:

- (1) 40 gallons per day per capita go to frontage consumers.
- (2) 47 gallons per day per capita go to meter consumers.
- (3) 10 gallons per day per capita go to free service.
- (4) 5 gallons per day per capita slip through meters unregistered.
- (5) 40 gallons per day per capita are lost through leaky plumbing fixtures.
- (6) 61 gallons per day per capita are lost through willful wastage and underground leakage in mains and service pipes, etc.

Items 1, 2, 3 and 4, amounting to 102 gallons per capita, show the water that is actually used, and items 5 and 6, amounting to 101 gallons per capita, show the water that is lost through wastage and leakage.

87 gallons per capita produce all the revenue of about \$6,000,000

per year, and 116 gallons produce no revenue. In other words, about 43% of the water delivered to the mains produces all of the revenue, and 57% produces no revenue.

In European cities the pumpage of water per capita is only from 15 to 50 gallons per day.

The following table gives information on this subject in detail:

WATER SUPPLY OF EUROPEAN CITIES.

City.	Population.	Date.	Daily Consumption per Capita.		Total
			Domestic Supply.	Public and Mfg.	
London	7,429,740	1909	27	8	35
Paris	2,846,986	1911	18	30 4/5	48 4/5
Berlin	2,101,983	1908	....	....	17 1/5
Vienna	2,031,000	1910	9	6	15
St. Petersburg	1,870,000	1910	....	....	40
Calcutta (about)	1,217,000	1910	....	....	24
Glasgow	872,000	1909	34	20	54
Hamburg	802,793	1905	....	....	37 1/2
Liverpool	768,000	1909	18 1/2	13	31 1/2
Budapest	732,322	1900	....	....	....
Manchester	716,000	1909	16 1/2	13	29 1/2
Birmingham (about) .	680,000	1908	15 1/2	9 1/4	24 3/4
Munich (about)	595,000	1910	....	....	20 1/2
Dresden	546,000	1910	....	....	21 8/10
Cologne	516,000	1908	....	....	26 2/10
Frankfort on Main...	415,000	1908	....	....	38
Breslau	512,000	1905	....	....	16 3/4
Dublin	403,000	1909	29	7	36

Conditions in European cities as to facilities for use of water, are, of course, quite different from those in American cities. The plumbing fixtures are not as numerous as in American buildings, and the opportunities for use and waste of water are much more restricted.

But even American cities, where the conservation of the water supply has been taken up more seriously, show conditions as regards the per capita consumption that are vastly different from those in Chicago.

The following table will serve as an illustration to show the relation of meters to per capita consumption of water:

WATER SUPPLY OF AMERICAN CITIES.

City.	Per cent. of services metered.	Consumption U.S. gals. per capita per day.	Population Gov't Census, 1910.
Buffalo, N. Y.	4.5	317	423,715
Cambridge, Mass.	30	100	104,839
Chicago, Ill.	5.9	200	2,185,283

Cincinnati, O.	46.3	131.3	364,463
Cleveland, O.	98.3	104.3	560,663
Detroit, Mich.	11	187	465,766
Houston, Tex.	82	53	78,800
Lowell, Mass.	81.6	50.5	106,294
Milwaukee, Wis.	98	113	373,857
Newark, N. J.	54	107	347,469
Philadelphia, Pa.	2	201	1,549,008
Pittsburgh, Pa.	11.9	236	533,905
Providence, R. I.	90	65	224,326
Richmond, Va.	68	98.3	127,628
Rochester, N. Y.	99	91	218,149
Toledo, O.	90	87	168,497

In Chicago and in most of our American cities people pay for their water largely on what is called the frontage rate principle. That is, the size of a lot and the size and character of the building and water fixtures thereon are recorded, and on this basis the owner is taxed for the water used. There is no effective restriction to the use of the water. With somewhat similar lots and buildings one owner pays as much as another, even though he uses ten times as much water. Imagine other commodities, as gas or electric power, being sold in that manner. Water is allowed by many to run constantly during the summer to save a little money in ice, and likewise during the winter to save coal and for fear the water will freeze in the pipes. Plumbing fixtures are neglected, and allowed to leak, to the detriment of both the water fund and the health of the citizens.

LONG HOPPER CLOSETS.

It is estimated that there are over 60,000 so-called long hopper closets in use in the city of Chicago. The Water Survey Division of the Bureau of Engineering a year or so ago, when one of these closets was found running continuously, installed a meter on the service, which registered 10,000 gallons of water daily for sometime after installation.

In the Report of the Department of Public Works for 1911, on page 163, hopper closets are described as follows:

"A long hopper closet is a sanitary device, used for water closet purposes. It costs less to install than closets with flush tanks and can also be used outside or in basements where a moderate amount of freezing will occur. The various controlling devices used to regulate the supply for hoppers are inexpensive fixtures and are apt to get out of order easily. In addition, a part of the device is under cover and difficult to get at, so that maintaining them in good order is a burden to the consumer."

European cities, as stated, have long since seen the absurdity, loss, and waste of this method of selling water, and are universally using water meters, which accurately measure the quantity used by each consumer. The result of this logical and sensible method is an ample supply with adequate pressures at all times. Everybody is

treated alike. The water costs the consumer less, for it is evident that the American consumer has to pay indirectly and proportionately for all the loss and waste, as well as for the water he actually uses. Not only is this true, but the citizen who keeps his plumbing in good order and uses water properly has to pay for the neglect and carelessness of his neighbor. The metered consumer also has to pay for the extravagances and waste of the frontage consumer, for with a properly restricted system the rates could undoubtedly be reduced.

What will we come to if the present wasteful methods are permitted to continue?

Chicago in 1950 on the basis of past and present increases will, by the most conservative estimates, have a population of 5,150,000. The consumption of water per capita has increased from 43 gallons in 1863 to 203 gallons in 1912, or about 160 gallons in 50 years. If we assume that the increase in per capita consumption in the future be only at one-half the rate of the increases in the past, we will still in 1950 have a per capita consumption of 263 gallons. This will require a daily pumpage in 1950 of 1,350,000,000 gallons, or, in other words, the present enormous system must be more than doubled in 38 years.

Nearly 15 years ago the author commenced a series of careful investigations to determine the use and abuse of the water supply of Chicago, and ever since he has periodically by special reports, by lectures, and in books earnestly endeavored to point out the advisability of conservation and the restriction of the waste and leakage of our water supply.

WATER METERS.

The best and generally approved method for this purpose is, he believes, the installation of water meters, a method that has proved economical and satisfactory in European and in those American cities where adopted. This method he has also repeatedly recommended.

In 1907 a Water Survey Division of the Bureau of Engineering was organized, as a result of the campaign for the restriction of waste, and the work of this Division has been fully described in the yearly reports of the Department of Public Works.

This method of water waste prevention requires house to house inspection and the compulsory repairing of plumbing fixtures. This is a rather troublesome matter to handle, as many property owners seem to consider that they are specially privileged and use every influence to avoid complying with such reasonable requests as the repairing of leaky plumbing fixtures in their buildings. The repairing of plumbing fixtures requires an effort. The property owner must obtain estimates from plumbers and probably award contracts, which requires expenditures of money. Unless his self-interest is appealed to, rather than his duty to expend money for the public good, the average man will do much to shirk this duty. Furthermore, inspections and surveys under this method must be repeated at intervals, as repairs of this nature are not permanent.

A water meter is a reasonable and automatic inspector, that is "on the job" all the time. If a man has an unlimited supply of water for which he pays at a fixed rate per annum, regardless of quantity used, he will not worry about leaky fixtures in his building or whether the water is allowed to run continuously. The water runs away principally through the soil pipes and sewers and causes him generally no annoyance and no expense, and to let it run requires no effort on his part.

Metering of the great number of services in Chicago would, of course, involve a large expenditure of money. Our present costs are high, since they are based on scattered jobs. The distances are great, methods of transportation are antiquated, and the time required in traveling constitutes a large part of the working day. Furthermore, the costs are increased by the persistent interference of property owners, who use every political influence and other means to stop or delay the installation of meters. When metering can be commenced on a large scale, this work can be organized and conducted on a much more businesslike basis, and the costs greatly reduced.

The author believes it is not advisable to advocate that all services in Chicago be metered. He believes that the greatest part of the benefits to be derived can be secured by metering not to exceed 50% of the services, if proper judgment is used in determining which buildings should be metered.

In the summer of 1911 the meter installation and repair work of the city was transferred from the Water Rate Collection Bureau to the Bureau of Engineering.

A statement showing the water meters installed during the months of August and September following the transfer was prepared, and about a year later a careful comparison was made showing the effect on rates of the installation of these meters.

During those two months the following meters were set:

Size.	Number.
$\frac{5}{8}$ in.....	2
$\frac{3}{4}$ in.....	93
1 in.....	102
$1\frac{1}{4}$ in.....	4
$1\frac{1}{2}$ in.....	14
2 in.....	21
3 in.....	10
4 in.....	6
6 in.....	5
8 in.....	4

Total.....261

These meters were set on all classes of service and in all parts of the city. They include saloons, foundries, railroad stations, residences, laundries, buildings with hydraulic cellar drainers, hotels, factories, garages, milk depots, greenhouses, fish markets, office buildings, warehouses, apartment buildings, photograph galleries,

and similar diversified service. In some of these cases more than one meter was included under one bill; in other cases the property had never been assessed, as they were new buildings. Therefore, the difference in these cases could not be included in the tabulations. Where the difference was obtained 124 premises showed an increase and 56 showed a decrease in the bills by the installation of meters.

The total of the excess meter rates for six months amounts to \$2885.15. The total of decreases, by reason of setting meters for a period of six months, amounts to \$494.68, making the net increase of \$2390.47, or \$4780.94 as the annual compensation for the setting of these meters. These figures indicate that if the placing of meters is judiciously made, irrespective of a decrease in pumpage, the city's revenues will be increased rather than diminished. Further comparisons are being made along this line with a view of establishing this fact.

Irrespective of the campaign for a restriction of leakage and waste and irrespective of the economy and satisfaction that water meters have given in other cities, so much opposition to this method has been and is met with in Chicago that only about 6% of the service pipes have so far been metered.

Designs for municipal water meters have lately been perfected in the office of the City Engineer, and sample meters made from these designs are now being tried out. It is hoped and expected that, as soon as these meters shall have proved satisfactory on trial and adopted as a standard meter for Chicago, the installation of meters on a much larger scale will be commenced.

One of the important reasons why Chicago has to pump such great quantities of water and why there is always such urgent necessity to build additional tunnels and pumping stations is the failure to adopt rational methods of water waste prevention. An argument often heard is that we have an inexhaustible supply of water right at our doors and that the water should be as free and abundant as the air we breathe. If this excessive pumpage would benefit the people, there would be nothing to say about it. But, as a matter of fact, the wasted water does no one any good, and when escaping into the ground it often becomes a detriment rather than a benefit.

When it is further considered that the cost for coal alone to pump the many million gallons of water in Chicago is now about \$450,000 per year, it will be seen that by reducing the per capita consumption from 203 gallons to, say, 120 gallons per day, which should be sufficient for any city, a saving from this item alone would amount to nearly \$200,000 per year.

When also the additional cost on account of larger pipes required to carry the excessive quantities of water, other operating expenses, and the interest on cost of tunnels and pumping stations that could be delayed under proper restrictions be considered, the saving per year would amount to many thousands of dollars more.

GENERAL IMPROVEMENTS OF PLANTS.

It has been our constant endeavor not only to add necessary

constructions to meet the rapidly increasing demands for water, but also to modernize the system and to increase the efficiency year by year. Modern and up to date machinery to replace that which is old and inefficient, has been installed as fast as appropriations could be obtained for such purpose. In past years recommendations made by the City Engineer could generally not be acted upon for several years and sometimes not at all, the funds available being insufficient to meet the great demands for improvements. Many other difficulties, which cannot be gone into on this occasion, are met with in a position of this kind.

An accurate knowledge of the amount of slip in the pumps at frequent intervals was important. For years the records of pumpage were based on plunger displacements and by estimating the percentage of slip, if slip was considered at all. To obtain this information with reasonable accuracy, recording Venturi meters were recommended about ten years ago, and later installed on the discharge mains on some new pumping engines. The appropriations for this purpose came slowly, however. Many indicating and recording pitometers have also lately been installed, so that in the very near future all of our pumping engines will be equipped with means for accurately measuring the actual discharge. In this way the condition of the pump valves of each engine is carefully checked at all times, and immediate repairs to or replacement of the same can be made when required.

Considerable discrepancies in the pressures reported from our various pumping stations, due to error in pressure gauges and elevations used in computing heads, appeared. For this reason a special design of mercury columns has been prepared, and these instruments now being made will soon be installed in all pumping stations.

Investigations are made and work done under the direction of the City Engineer to bring the water supply system of Chicago to a modern basis. As is the case with many public works in Chicago, investigations have also been made by others not connected with the Department of Public Works. Such investigations were made about three years ago by an engineer of some standing selected from outside of Chicago. As his report has been printed and distributed, some comments on his findings may be permitted. He fully endorsed the author's campaign against water waste and leakage.

As regards the economy of operation of the pumping stations, this investigator makes a comparison between Chicago (taking an average of eight stations, old and new,) and the water works of Cleveland, Ohio, and Milwaukee, Wis.—municipal plants with one modern station in each city—and Peoria, Ill., a private plant. He determines the horse power and finds the total amount of the pay roll of each pumping station, and then arrives at the number of horse powers per dollar of daily pay roll at each place. (It is not stated on what basis the numbers of horse powers are obtained.)

In some tables accompanying the report he gives the average pay per man per day at the various places. This shows that the sal-

aries paid to the men employed in the water works by the City of Chicago are considerably higher than those paid in Cleveland and much higher than those paid in Milwaukee and Peoria. This fact, of course, makes the ratios referred to show unfavorably to the economy of Chicago operation. He then attempts to bring these ratios as shown for Chicago stations down to the ratio shown for the other cities, where the salaries of the men are lower, by recommending a reduction in the number of men in the pumping stations in the City of Chicago.

Using the data presented in his tables and making salaries paid in each of these cities equal to the salaries paid in Chicago, it can be found that Chicago shows up unusually well in comparison with the other cities selected.

In his analysis of and his recommendations for a reduction in the number of men of various classes employed in the various pumping stations by the City of Chicago, one instance may be mentioned, as it is more or less characteristic of all. In the main engine room at Chicago Avenue pumping station there are three 25,000,000 gallon Reidler, vertical, triple expansion pumping engines measuring about 50 ft. from basement floor to top of engines. These engines make about 60 revolutions per minute. Each engine is provided with an independent air pump and other auxiliaries. The city employs one oiler for each of these engines per watch. Judging by his recommendations, the investigator evidently contends that one oiler per watch for the entire set of three engines would be sufficient. It is not thought prudent to leave three such large and complicated machines, representing an investment of about \$300,000, in the hands of only one oiler. Besides, these employees are needed to perform other duties on many occasions.

The salaries of all city employees are established by the City Council. It is admitted that the salaries paid to the employees of the pumping stations in Chicago are higher than in any city of the United States. This fact, however, should not be used as evidence to show alleged inefficiency in the management of the system.

As regards economy in general, it must be taken into consideration that until this year there were practically no reserve units for emergency demands and hardly enough engines to supply the average demand. This being the case, it became necessary to operate the engines continuously until they had to be stopped by breakages or other compulsory reasons. In other words, many pumps had to be kept in operation under most uneconomical conditions because of absolute necessity.

Recommendations for improvements in the system were made in the report just referred to, which, as the investigator well knew, had been under consideration by the Department engineers long before he came upon the scene and in some instances already acted upon. It is stated in the report referred to that "more thorough investigation would probably have been advisable and profitable, but that lack of time and funds prevented this course." As a matter

of fact, no investigation of a large and complicated system which was not thorough could have been profitable, due to numerous phases affecting the operation of the pumping stations and to the diversity of opinions as to the best results even when the real facts are known. There was not one scientific test made by these investigators at any of the pumping stations, on which to base any conclusions. Whether there were insufficient funds to make a proper investigation, the author does not know. Certain it is that the conclusions of this investigator are similar in character to the shooting of birdshot into a flock of ducks. There are many misses and some hits. A few recommendations based upon careful and thorough investigation would have been of value to all concerned.

ELECTRIC POWER OPERATION.

Much has been heard and said about the advisability and economy of equipping the pumping stations with machinery operated by electric power generated by the Sanitary District. Considerable thought has been given to this matter by the Department engineers, and careful investigations, plans and estimates are now being made to further determine the advisability of such changes. As these investigations have not been completed and the entire matter undoubtedly will be the subject of a subsequent paper, no details are here presented.

Two electrically operated, motor driven, centrifugal pumps, each of about 25,000,000 gallons capacity per 24 hours, have been installed at the Ashland Avenue pumping station for experimental purposes, and these have now been operated since January, 1912.

Careful comparative estimates based on actual running factors at this and other city pumping stations and proportioned to a plant of 100,000,000 gallons capacity per 24 hours show the total annual operating expenses for the electrically-operated station to be \$156,-330 as against \$90,780 for a modern steam driven reciprocating plant. Of course, fixed and other charges must yet be compared before any conclusions can be drawn as to the relative economy of the two plants.

A serious matter in connection with the electrically-operated pumps at the Ashland Avenue plant is the frequent interruptions in electric power supply. During the year 1912 the stoppages due solely to interruptions in electric power supply amounted to 28, varying in length of time from a few minutes to 20 hours and 30 minutes.

PRESENT AND PROPOSED SUPERVISION.

Aside from the construction, maintenance, and operation of the water supply system, the City Engineer of Chicago has to supervise the construction, maintenance and operation of some 100 bridges and viaducts, docks and harbor work, subways, and other constructions involving millions of dollars of expenditures.

In addition to his regular duties as City Engineer, he has also acted in the following capacities:

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1898-1901, Member and Engineer, Board of Local Improvements.

1898-1912, Member, Board of Automobile Examiners.

1909-1910, Member and President, Board of Examining Engineers.

1911 to date, Chairman, Harbor and Subway Commission, and other assignments.

The author does not claim that the water supply system of Chicago is as modern or as efficient as it can and might be, but he does claim that everything is being done to bring about such desired results as rapidly as the conditions will permit.

The author expresses as his opinion that the magnitude of Chicago's water supply system requires the organization of a Department of Water, embracing all the divisions of the service, including the collection of rates, to be managed by a Board or a Commissioner of Water with no other official duties. Under a properly qualified head with no other duties, the efficiency of the water supply system of Chicago undoubtedly could be more rapidly improved.

DISCUSSION.

Langdon Pearse, M. W. S. E.: We are greatly indebted to Mr. Ericson for his interesting statement of the past and present condition of the city water works. It is a remarkable indictment of modern conditions in next to the largest city in the United States, along the line of extravagant water use. However, the conditions are typical of many other cities in this country, and even of some of Chicago's neighbors. Evanston is a remarkable sinner in the same respect; perhaps to a greater extent in percentages than Chicago. Recently I made an investigation in Evanston, and found an average use of 200 gallons per capita daily per year, with a maximum of 400 gallons per capita daily in the summer time on the basis of 30,000 people, with a peak load for four hours of nearly 600 gallons per capita. Yet this use of water is being reduced with difficulty because of the fear that the lawns will dry up. In Massachusetts, for instance, on the contrary, in the Metropolitan water district, which includes Boston, and particularly in some of the towns included therein where the entire water supply is metered, with a per capita consumption of 65 gallons daily we find ample lawns and comfortable homes. There is no trouble about the use of water in the homes.

Such comparison ought to bring home to every engineer, I think, the distinct and immediate need in Chicago for metering. I should be inclined to go further, yes, a good deal further, than Mr. Ericson, and not stop at 50% of services metered. I would like to see this figure go up to 90% and over. It is not easy to discriminate between users who waste and those who do not. Experience elsewhere has demonstrated that by first metering the economical users, even at a loss, their support will greatly aid in securing complete metering.

The results which have been accomplished in Cleveland are an object lesson. When we stop to think that the actual average use in Cleveland is the same as the average waste in Chicago, as indicated by Mr. Ericson, we can see that there is a very great opportunity for saving in interest and construction that has to be paid for, which might go a long way towards paying for universal meters. This is particularly true, if Mr. Ericson's suggestion of combining the operation and collection under one department is worked out, so that the reading of the meters, repairs, testing and the like can be systematized. This is a considerable element in the cost of the operation.

Colonel Henry A. Allen, (Bureau of Engineering): Regarding that part of Mr. Ericson's paper referring to investigation of mechanical affairs, it is my observation that investigators are, as a rule, a little careless, or the people who employ them are a little careless, in not supplying sufficient funds to permit making thorough investigations.

In regard to the investigation referred to in the paper, it was endeavored to make up a set of tabulations of comparisons between certain private power plants and certain municipal pumping plants with the several pumping plants in the city of Chicago. It was endeavored to make the basis of comparison on boiler horse power. This, in itself, would be erroneous without giving fair credit for differences in the types of engines, horse power, kind of service, arrangement of engine rooms, boiler rooms, platforms, and other factors effecting accessibility and convenience in operation. For instance, at 68th Street Pumping Station we have 21 oilers. Some of the engines are 24 years old or more. They are liable to break down at any moment, notwithstanding the fact that the Bureau of Engineering has done its best to put them in the highest state of repairs. They are working under pressures higher than that for which they are designed and at times have been obliged to be run not only at maximum speed, but even over the maximum speed for which they were designed. In this case, it would be almost criminal to run any risks in the supplying of water to the public. Should anything happen, the oiler must be ready to jump to the throttle.

In the city of Chicago at the present time there are probably but three engines provided with suitable safety governors that, in the case of the bursting of a water main or other cause tending to suddenly reduce the water pressure at the pumps, would stop the engines automatically and prevent them running away and going through the roof. I believe many of our engines would be seriously damaged in such an event.

As a matter of safety, more oilers are carried than would be the case were all engines of modern design and properly equipped. In other words, such extra labor can be charged directly to insurance.

Several of our engines have been running for 37 years and are doing good service, but we all know that metal gets fatigued, crystallizes; therefore we cannot afford to take chances.

As Mr. Ericson stated, he has made recommendations for improvements, and plans are fast being perfected to the end that Chicago may have the finest water works supply system in the world. Work on these plans is developing to good advantage. It is a pleasure to state that the Bureau of Engineering is working harmoniously and upon well conceived concrete plans.

Reference was made to electrically-driven pumps. In comparing systems, all factors should be taken into consideration. A steam-driven pump has the advantage of elasticity; it can be run fast or slow either under pressure or speed regulation without difficulty. This is not a fact with any other power than compressed air.

Reliability should be the first factor considered in a city's water supply, especially in so large a city as Chicago. To obtain the greatest reliability, each pumping station should be an independent unit, *i. e.*, a station independent for its primary source of power from any outside source. Then by the adoption of the triangular system, *i. e.*, the connecting of the various pumping stations by big feeder mains, in the case of one station being disabled by serious accident, the other two stations can readily furnish water to the district supplied normally from the disabled station.

Imagine Lake View Station, for instance (which supplies a population of approximately 240,000 in an area of probably 40 square miles), being put out of service for an hour, two hours, or three hours. Think what could happen in the case of fire; what surely does happen in inconvenience to the public; and what might happen in the way of epidemic.

Much criticism has been directed against the use of certain kinds of coal by the city pumping stations, to the effect that cheaper grades should be used. Let us stop to think of this matter. Several of our pumping stations are situated in residential districts; therefore it is desirable that the least amount of coal be burned, which means the installing of the most economical apparatus. To many of these stations coal must be hauled in wagons over one or more boulevards and the ashes taken away; therefore the coal which produces, within reason, the least ash and the greatest number of heat units causes the least inconvenience.

One cannot make improvements and have conveniences without the expenditure of money. The City Fathers have appropriated the large sum of approximately \$14,000,000 to be expended during the next four years for the improvement of the water supply system of the city of Chicago.

Mr. Pearce: May we hear from Mr. Samuel G. Artingstall, one of the former City Engineers?

Samuel G. Artingstall, M. W. S. E.: The author has given us a good view, or illustration, of what the Chicago Water Works was originally, and how it has expanded to the present time. I was in the City Engineer's office from 1869 until Mr. Ericson accepted the position as my successor. I was in the water works department

from the time the first tunnel was built. The increase of population and the annexation of adjacent territory compelled the extension of water mains and an increased pumping capacity. There has always been a prayer for more water. We could never furnish enough of it. We have always, too, been well aware that there was an enormous waste and we have done our best to establish a system of metering, particularly for small consumers, but a water meter is an expensive piece of apparatus in comparison, for instance, with a gas meter. In apartment buildings where there are from three to forty tenants, there is a gas meter installed for every tenant at a very reasonable rate. But with water meters the case is different, and under the present system each tenant cannot be assessed. The landlord has to pay for water for the whole building and the tenant does not care how much water he wastes because he does not have to pay for it.

If a system of metering could be established in apartment buildings whereby every water-user would be required to pay his share of the cost of metering, a great deal of the present waste might be reduced, and might result in obtaining a cheaper meter, for use inside the building,—perhaps a small Venturi meter.

I will ask Mr. Ericson what it costs to install the smallest water meter.

Mr. Ericson: We do not now install smaller than $\frac{3}{4}$ in. meters. If installed under proper organization, as would be the case if meters were installed on a large scale, we could install them complete, I would say, for about \$25.00 on old services and \$15.00 on new services, including cost of meter.

Mr. Artingstall: I think gas meters can be installed for two or three dollars. If we could secure a water meter which could be installed for a moderate price, I doubt if we could get a pit with cover and equipment put in the ground for the smallest meter at the price named. It must be protected from frost and zero weather in the winter time.

Mr. Ericson: Of course, we have precedents in other cities. If it works out all right elsewhere, there is no reason why it should not in the city of Chicago.

Leroy K. Sherman, M. W. S. E.: I came here this evening with the desire to learn rather than to say anything, but after listening to Mr. Artingstall I have a little more nerve, perhaps, to take exception to the meter proposition. I have felt that there are two sides to that, and, judging from the points on Mr. Ericson's curve, the somewhat erratic way that the relation of meters to consumption went, I am inclined to think that there is not such obvious economy in metering as many expect.

Mr. Moore: I would ask Mr. Ericson how many kilowatts are required to pump a million gallons?

Mr. Ericson: I did not include that information because we intend to cover that electrical matter in another paper. Perhaps Col. Allen has some figures at hand.

Col. Allen: As we have been asked by the City Council to make a thorough investigation, I do not feel at liberty to present those figures this evening.

Horace S. Baker, M. W. S. E.: I think this has been a very valuable discussion of conditions in Chicago. There is one point that is brought out too much in discussions of metering, I think, not only in Chicago but in general; that is, the saving of expenditures for pumping and for constructions. That is the argument generally used. But it has always seemed to me that it is not so much the *saving* (one can figure out how much is saved, how many millions of gallons at so much money value); but the real advantage of saving water and saving waste is the ability to give service, and that is the only way I can see that we will ever get it. At the present time if we raise the pressure in any district, we have to greatly increase the amount of water pumped into that district. If there are faucets left open, leaky plumbing and other sources of loss, the leakage increases very rapidly with the pressure and one must keep the pumpage going up much faster than the pressure increases. This was plainly illustrated when we put the new Roseland pumping station into service, also when we started our new booster station on the Northwest side. That has always seemed to me to be the principal reason for restricting the waste of water. If we do not restrict the waste of water we will go on forever increasing systems of pumping, but we will never give satisfactory service except at an enormously increased cost.

The argument of cost and saving construction is apt to be misleading, in another way, because I do not think the city of Chicago can stop water works construction, even if the waste is greatly reduced. The city is growing so rapidly that we must build these new stations. We must put in these two tunnel systems and this Northwest pumping station, also the pumping station Mr. Ericson mentions down on the Southwest side. But that is the experience of all public utilities in Chicago. The Commonwealth Edison Company does not waste much power, but just as soon as it finishes one station it starts another to keep up with the growth of its business. The point is that by stopping this waste of water we shall get the good of our stations and be able to deliver service.

COÖPERATION AMONG ENGINEERING SOCIETIES

RALPH D. MERSHON, MEM. A. I. E. E.

Presented at Joint Meeting of Electrical Section W. S. E. and Chicago Section A. I. E. E. April 28, 1913.

I had not appreciated, until a few moments ago, that this is not a general meeting with a paper for discussion. I thought my part in it would be extremely small. So, if the talk I shall endeavor to give does not run along as smoothly as it might, I hope you will bear in mind my unpreparedness.

This meeting is a rather unusual one, so far as I am concerned, because it is the first time I have attended a joint meeting of a Section of the Institute and a Section of any other society. I believe there is closer coöperation in Chicago among the engineering societies, or some of them, than in any of the other centers of the United States. As a result of your coöperation here, there is a tendency toward greater coöperation elsewhere, so that the work which you have started here is not only good in itself but will undoubtedly lead to very desirable results in other cities.

There is no question of the desirability of close coöperation among national engineering societies. There has been more or less coöperation in the past among the national societies, but mainly on matters of policy rather than on technical matters. For instance, one matter has lately arisen in the state of New York, which has been referred to the Conference Committee of the National Societies. (Perhaps some of you do not know that there is a permanent conference committee in connection with the four national societies.) This matter that has lately come up in the state of New York for the third time in as many years is a bill before the legislature of the state of New York on the licensing of engineers. Most of the members of the national engineering societies with whom I have discussed this question are opposed to any bill for licensing engineers. I am personally opposed to such a bill for the reason that if the states start in licensing engineers it will hamper the work of engineers in different states. If a man is called upon to do some work in a state other than his own, he will have to find out first whether licenses are required in that state, and, if so, he will have to secure a license. This will mean delay and trouble.

The bill before the New York legislature had a good many objectionable features, and, although it was killed this time, similar bills will undoubtedly come up in the future. Because of this fact, the New York members of the national engineering societies, although most of them do not approve of licensing engineers, seem to have come to the conclusion that it will be necessary to get together and draw a bill. Undoubtedly, therefore, the societies, acting jointly, will, at the next session of the New York legis-

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lature, have a bill which they will offer as an alternative to any other bill that may be offered, probably with the statement that they are not in favor of a bill for licensing engineers, but in case a bill is demanded, they prefer the one they offer.

That is an example of the sort of work that has usually been done when the national engineering bodies have acted in coöperation, although in some cases they have coöperated also in technical matters. As a rule, I think coöperation in technical matters has been between the American Institute of Electrical Engineers and the American Society of Mechanical Engineers, although there has been some coöperation along this line with the American Society for Testing Materials, and there may be some, shortly, with the American Institute of Mining Engineers. This is all a very healthy tendency, I think, and the subject may well be discussed this evening.

At the dinner I had the pleasure of attending before coming to this meeting, the subject was discussed to some extent, and in order to draw out discussion it might be well to raise some of the points that were raised then. Those discussing the matter at dinner seemed to look toward a time, perhaps in the very indefinite future, when there might be a general engineering society, a national engineering society, which, if it did not include all of the present engineering societies and their work, would more or less coördinate their work. I think there is some question as to the desirability of an engineering society which shall include all branches of engineering. As you may perhaps know, the accepted meaning of the term civil engineer in England is, any engineer who is not a military or naval engineer. That is the meaning held to by the American Society of Civil Engineers, although in this country the usual meaning of the term is not nearly so broad.

One of the questions raised was as to what would have been the outcome today if we had had, from the start, a society—a civil engineering society, we will say—including all branches of engineering, and whether the activities of the separate engineering societies that we have now,—the civil, mechanical, mining, and electrical,—would have been as intense as they have been. For my part, I doubt whether

taking the electrical society, for instance, because I have more intimate knowledge of its work—the activities would have been anything like what they have been if the society had been part and parcel of another large engineering society, as, for instance, the American Society of Civil Engineers. So that, if we were going to have a general engineering society, the question would arise as to how it could be so constituted as to get such benefits as might result from the consolidation of the societies and not forfeit the benefits that are the result of the separate societies; whether this is possible and how it could be brought about.

I would like to bring to your attention a question which the American Institute of Electrical Engineers will have to face very

soon, and which it is beginning to face now, analogous to the one which would have to be faced in a general engineering society (or in a "holding" society, if I might use the term), under which all societies now existing would be correlated. In the American Institute of Electrical Engineers, as most of you know, there are technical committees carrying on different lines of work. We have a high voltage transmission committee, a power station committee, an electric light committee, a committee on the use of electricity in mines, etc., each committee looking after the particular line of work in which it is immediately interested. There is more or less pressure brought to bear, from time to time, for the formation of additional committees; undoubtedly the formation of these committees would be a good thing. It is desirable to increase and encourage our activities along different lines, and not hamper them in any way. But there is this difficulty,—the formation of a new technical committee means more expense. Of course, it means a certain number of new members, but not, in general, enough to increase the income sufficiently to cover the increased expense resulting from the creation of the new technical committee, and the new work that it will take up. So that, if such expansion in the Institute continues, we shall be up against the question of either increasing the income or decreasing the expenses.

It seems to me a similar difficulty will arise if the endeavor is made to bring the national engineering societies more closely together. If they are brought together without decreasing the income of any of the separate societies, then possibly there can be enough economies effected because of their being brought together, to take care of the general expense resulting from the consolidation, if we choose to call it such. But the working out of an effective scheme will not be easy, and I think the subject might be a profitable one for discussion this evening; (1) the desirability of consolidation, and (2) the ways and means, if it seems desirable.

The fact that you are coöperating here brings to my mind another matter I have urged more or less on the local sections of the Institute, and which can properly be a good deal more strongly urged in the case of local coöperation among engineering societies; that is, the desirability of engineers taking a greater part than they have heretofore, in public affairs, especially in the civic affairs of their immediate community. There has not been enough of this in the past. You can very profitably devote some of your meetings to the discussion of civic engineering problems not necessarily those, only, that are immediately concerned with your own particular technical work as engineers, but problems of a more or less general engineering nature. Almost all, if not all, economical problems are engineering problems. Whether or not the result of such discussion could properly be made public as being the result of a discussion, there may be some question; but there is no reason why the individuals taking part in such discussions should not bring to bear in public affairs the conclusions that they have arrived

at, the ideas that have been crystallized in their own minds as a result of those discussions.

The engineer has not in the past taken the stand he should have taken in civic affairs. For that matter, most of the better citizens and thinkers have not taken the part they should have taken, and they, themselves, are largely to blame for the very things of which they complain in both civic and national affairs. We grumble and growl about things not being as they should be, and, after all, it is our own fault. No man is better fitted to cope with any of these civic problems, analyze them, and arrive at a conclusion, than the engineer. He should, therefore, do his full duty in that direction, and I believe that in these joint meetings you can, by discussing some of these civic problems, do a great deal toward influencing engineers to take the part they should in civic matters.

In that connection it might interest you to know that in some European countries the method of handling civic affairs is quite different from the method in this country. For instance, in Germany the work of being a mayor is a profession. The cities hire their mayors. The mayors are not elected, they are hired. Sometimes one city will hire a mayor away from another city. Recently, there was an advertisement in one of the German technical papers for a mayor, and it specified that he should be an engineer. I think the endeavor to get engineers in the governing bodies of our cities could be followed with very great profit in this country.

The question of coöperation among engineering societies gives me an opportunity to bring up for discussion a subject in which I have been much interested for many years, and that is the improvement of the patent system of the United States. This is a matter in which engineers should coöperate. I doubt if the citizens of the United States, even the engineers, a great many of them, realize just what the patent system of the country means to the country. I think it cannot be successfully disputed that there is no other one thing that has done more in the past to make life easier and to free society from the grasp of special privilege than invention. As far as making life easier is concerned, all one has to do is to look around. As far as the freeing of society from the grasp of special privilege is concerned, I might cite one invention, that of gunpowder. That is perhaps one of the first and most striking examples. Invention can, and will if properly fostered, do much more in the future.

Take, for instance, the matter that has been agitated in this country for quite a while—as to what is to be done with regard to industrial combinations: whether this country is going to permit industrial combinations and regulate them, or whether it is going to try to preserve competition by preventing combination. If the patent system of the United States did approximately what it purports to do, the question of competition would largely take care of itself. If the small manufacturer could know, when he invented

something or when he bought an invention and made it the basis of a business, that the patent would amount to something in the way of protection and that some one could not come along and take away from him the fruits of his labor, then there would be small manufactories springing up continually all over the country and they would be able to compete with the large concerns. But this is not the case.

Suppose a man owns or purchases a patent and builds up a prosperous business, or what bids fair to be a prosperous business; there are a number of different ways in which he may be bitterly disappointed. In the first place, he may be notified some fine day that he is infringing a patent owned by a certain other company which has at its back much greater resources. Then he is in the position of having either to fight in the courts a needlessly long suit which may finally leave him nothing, not even the patent, or compel him to sell out on another's terms.

Our patent law provides that a patent shall be given to the original inventor, but it is exceedingly difficult to find the original inventor. One may apply for a patent on a piece of apparatus, have it issued, and start a small manufacturing business. But he may not be the original inventor. In the course of a few years some one may come along and prove that he was the original inventor. If he can do this, the Patent Office will give him a patent to supersede yours, and there you are with your business landed high and dry, together with the money you have invested in it.

In the past many suits have been brought with the deliberate intention (I know what I am talking about now, I am not talking from hearsay, but from actual knowledge) of squeezing out the little fellow. If it could not be done by invalidating his patent, then by dragging the suit out to such interminable length that he would finally be very glad to sell out at a small figure. I have known of cases where a little man's patent has been infringed because of the knowledge on the part of the company infringing, that, having plenty of money to fight with, they could drag the suit out indefinitely, and that even if the little man finally got judgment against them, he could not collect any more than he could have collected on royalties.

Suppose one has a patent suit in one of the nine circuit courts of the United States and he wins in that circuit; that decision does not necessarily rule in the other eight circuits. He must fight out eight other patent suits before he gets through.

The new rules in equity recently promulgated by the Supreme Court will, in the opinion of a good many patent attorneys, change that condition to a considerable extent. It will probably be much easier than heretofore for a man of small means to defend himself in a suit or to prosecute a suit.

I desire to impress upon you the importance of this question, not merely to the inventor but to the whole country. The inventors as a class, the men who spend their time and energy and money

trying to develop things, get very little for the work that they do. Once in a while some invention makes a "ten strike." The individual inventor, however, in that particular case, probably gets very little, and in what little he may get he is an exception to the great mass of them. There are many inventors who get no reward whatever.

I will admit that there are many inventions that ought never to have been made, and that are not worth the paper the patent is printed on. Nevertheless, the general effort represented by inventions is well worth while, and I think we should do everything we can to foster it. This general effort makes for the general good, and undoubtedly the public gets in return far more than the inventor ever gets, either as a class or as an individual. After all, the method for compensating the inventor is about as fair, from the public standpoint, as can be imagined. He is not given anything positively; he is not paid any money. If he has made an invention which has the germ of industry in it, he gets his return, if he gets any at all, only after the invention has been developed. It is only a contingent reward that is given him, a monopoly, and it is only a limited monopoly at that, limited to seventeen years. Many people think seventeen years is too long a time. Not long ago I had the pleasure of being in the company of a number of inventors, among whom were some of the most distinguished in the country. One of the subjects that came up was as to the average time between the formulation of an invention and when it is successfully put upon the market, if ever. It was agreed that probably nine years was a fair figure on the average. In other words, out of the seventeen years, nine years will elapse before the invention can possibly show any returns, leaving just eight years in which the inventor can try to get his reward.

There are two definitions of a patent. One is that it is *prima facie* evidence that one has a right to be in court, and the other is, it is the right to have a lawsuit. A patent today does not mean anything until it has been adjudicated, and generally by the time one is through with the adjudication the patent has run out.

I would not have you think for a moment that I consider our patent system entirely defective, because it is not, by any means. In many ways we have the best patent system in the world. Our organic patent law, with possibly one or two small exceptions, is all right, but the details of the patent system, a good many of them, are quite wrong. Many of these things could be righted, but the manner in which they should be righted is a question. I find there are as many different opinions about this as there are men to discuss the law. If we should get a number of men together to discuss the specific details, we would find they would not all agree on the course which should be pursued.

One thing which would undoubtedly greatly modify and improve the situation would be an improvement in the Patent Office itself. Take, first, the matter of building. The Patent Office today is a ramshackle affair. It is a fire-trap. It would be an industrial

calamity if it should burn down, thereby destroying records of inestimable value; yet these records are housed in that building which is not fireproof. The floors are overloaded, and the employees and their work are hampered for lack of space. It is the more exasperating that it should be so when we consider that the Patent Bureau is the only branch of our Government that is self-supporting. In fact it has shown a profit. During the existence of the American patent system there have been covered into the Treasury of the United States as profits from the Patent Office, over \$7,000,000; yet our national legislators will not spend a part of that money to provide a decent building for the Patent Office and the great work that is carried on therein.

Next, the search system in the Patent Office is not nearly so thorough as it could and should be. If it were more thorough there would be less likelihood of some of the things of which I have just spoken, and a patent when issued would mean more than it does at the present time. The lack of thoroughness of the search is due mainly to lack of facilities and lack of a sufficient and able force. The salaries paid are so small that the moment one has demonstrated the fact that he has ability he is hired either by one of the numerous patent firms of the United States or by one of the large manufacturing companies.

In addition to the improvement there could be in the mechanism of the office, there are a considerable number of changes that might be made in the procedure in the way of interferences and in other matters.

There are a great many modifications that could be made to advantage in our patent system outside of the Patent Office, as I have already indicated. For instance, if we had a court of patent appeals corresponding to the Supreme Court in constitutional matters, whose judgment would answer for the whole country, then the anomalous condition already mentioned, of possibly having to sue on a patent nine times, would be removed.

There are three things in connection with the German patent system which are commendable. One is this: After the examination in the Patent Office there is a contestation period. If the examiners conclude the patent is allowable, the patent is published for a period of two months before it is issued. During the two months anyone can make objection to the issuance of the patent, but he must back up his objection by one or more citations of either previous publication or previous practice. It does not require a lawyer to do this; anybody can do it. The Patent Office will investigate all the objections made and if they find that any of the matter cited anticipates, the patent will be refused. If none of it does, they will overrule the objections and at the end of the period of contestation, issue the patent. Within a period of five years after its issue, action can still be taken to annul a patent, but after that period it is very difficult to do anything further.

I have indicated to you some of the faults of our patent system, and ways in which I think some of them could be remedied. I believe, however, the subject is such an important and difficult one that no attempt to improve the system should be made until after a very careful study of the whole subject has been made by a body of men appointed for that purpose. As I have already said, if we should call together a number of men interested in the patent situation to discuss it and the possible improvements, we would find there are about as many ideas as to what ought to be done as there are men who discuss the matter. About the only thing I have found that men will agree on is a commission to study the whole question. I think, therefore, that we ought to have a commission,—an independent, non-partisan, non-political commission. We can secure that kind of body if the members serve without compensation, but the moment compensation is attached to a job it becomes political, and it is then very difficult to obtain the proper results. It is entirely possible to have a commission of the very highest grade of men serving without pay. They should be men from divers walks of life,—not all patent lawyers, not all engineers or inventors, not all financial men, not all educators, not all business men, but representatives of each of these classes. The commission will then represent all interests concerned, and the result of their findings will be the best compromise under the circumstances. We cannot expect them to work out a scheme that will suit everybody.

The idea is that the commission will study the question in the light of all the information they can possibly get. They ought also to have the power to call witnesses, if they cannot get enough volunteers, and compel their attendance. Because the patent system is so intricately interwoven and interlocked with our industrial life, and that means with our every-day life, I believe that no one man can solve the problem. He may consider a change in one direction, which looks as though it would be good and as though it would remedy one defect, but after discussing it with some one else or considering the problem further, he may find the change proposed affects the system in entirely different and additional directions that had not been considered. A commission, composed of men from different walks of life, will study this problem, and each member will look at it from the viewpoint of his own particular interest. The final result will be a well worked out, well coördinated scheme, on which all of the members can agree and base recommendations for such legislation as may be necessary. Having these recommendations before us, we should all insist on the passage of the necessary legislation.

A very good example of a commission of this sort is the one appointed by William H. Taft some time ago to report on the subject of railway securities. It was made up of very able men indeed, serving without pay. The report is exceedingly interesting and valuable. I believe that same sort of a commission could and should be formed to deal with this patent situation, and I sincerely hope

you will not only discuss this question, but that you will do more,—bring to bear all the pressure you can to secure the appointment of such a commission, together with provision for the expense.

DISCUSSION.

W. F. M. Goss, M. W. S. E. (chairman): It is a great pleasure for me to be with you this evening and to join with you in the deliberations and pleasures of the hour.

We have a little time now in which to discuss these important questions which have been proposed and outlined for us. Mr. Mershon comes from a city down by the Hudson, where the civil engineers live uptown, the mechanical engineers live upstairs, the electrical engineers live downstairs, and so on. Now he has come to a town where the electrical engineers, the mechanical engineers, the civil engineers, are all on the same floor, in the same room, at the same time. It is a most auspicious occasion for the discussion of the question of mutual help, which he has proposed, coöperation,—a term by which we charm people and which it is particularly fitting that we discuss, as engineers, with reference to our relations toward one another and the relations of our organizations toward one another.

Now let us have six or eight five-minute speeches, growing out of Mr. Mershon's introduction of the subject of coöperation or any aspect of that coöperation which we may choose to bring forward.

Mr. Reichmann, the President of the Western Society of Engineers, will speak first.

President Reichmann: I am thoroughly in accord with the idea of the coöperation of engineers. I believe that Chicago is one place above all others where the engineers of a community should be housed under one roof. This city, in addition to being a great commercial center, is rapidly becoming one of the greatest industrial centers. It can boast not only of being in the greatest agricultural district in the world, but also of having resources which are necessary for industrial development, namely an abundance of coal and iron ore. The interests in and around Chicago are diversified, inasmuch as Chicago is a great financial and industrial center, and there is every reason to believe that it will not only hold its own, but will continue to grow and maintain its position as one of the largest cities in the world.

Owing to the rapid growth of Chicago there are many things to be done by the engineers, either in the way of reconstruction or new developments; consequently there is a great field for the engineers in this community.

All of the great national engineering societies have their headquarters in New York. The local members of these societies would derive a great deal of benefit by organizing local chapters, and in turn becoming a Section of the Western Society of Engineers. Such affiliations of the various engineering societies would certainly be of

great benefit to all of us, as we would not only be afforded a chance to become acquainted with one another, but we would also be benefited by each other's experience. This particularly will be necessary since industry is becoming so involved that there is scarcely a plant of any magnitude that does not require the services of practically every kind of an engineer.

One of the advantages to be gained in having the engineers of this community under one roof, would be that we could afford to have an extensive library with pleasant meeting rooms. The different branches could use the meeting rooms on different nights of the week, and in this way have better facilities than would be the case if we attempted to maintain a separate corporate existence.

A question which Mr. Mershon also brings up, is the one of legal status of the engineer. I dwelt on this question to some extent in my inaugural address as President of the Western Society of Engineers. I feel a great deal as Mr. Mershon does on this subject, namely, that I prefer not to see the engineers under control of the state if it can be avoided. However, there are many sides to this question. It is unfortunate that laws have been passed which make it almost necessary for engineers of certain branches of the profession to seek a license. In the state of Illinois there is an architect's license law which is drawn so broadly that any structure with a roof and sides shall be constructed by an architect. Thus it becomes impossible, according to the law, for an engineer to design an ordinary industrial building which is purely an engineering problem. For this reason, the Western Society of Engineers is coöperating with the state legislature in trying to have a bill passed which will permit the licensing of engineers and give them the same rights as an architect for certain classes of work.

P. M. Chamberlain: It is with much pleasure that I have listened to Mr. Mershon.

The subject of unifying the interests and coördinating the efforts of the various engineering associations and societies has certain features on which we must all agree; but unfortunately all of the features that we may bring to mind do not in themselves coördinate. There are advantages very, very apparent to us all in the small intensive organization, specializing along some particular line. There is the advantage of having all of its members of one mind as regards the general aim; their interests are in common; the same subjects interest them; they all have ideas on the subject under discussion sufficiently differing, and in the small gatherings they will express themselves and discuss and argue and perhaps raise considerable heat. This latter is an ideal condition. The larger the society, the broader the scope, the greater the diversity of the individual and special interests; and there must naturally be a less intensive condition as regards individual responsibility.

We can think of the ideal of having a central engineering library where librarians and attendants are specialists along differ-

ent lines. If one had fifteen minutes to spend in the library he could telephone to the library in advance and have prepared for him a list of all the publications and articles which had appeared in the technical press or had been published in books. This information would be ready for his use when he arrives, and he could immediately get the benefit of the centralized bureau. However, the tendency is to reduce expense; to have, perhaps, a library where there is only some one whose interest is incidental and accidental. It is quite impossible for one man, whose attention is given entirely to library work, to cover the entire field or even the field of technical literature. We perhaps appreciate this when we go down to the John Crerar Library, —a magnificent place, one of the finest in the country, although not so rich in engineering matter as some others,—where we have difficulty in finding, even with their trained staff of librarians, one who seems to know anything about the lines in which we happen to be interested.

It would be very interesting, too, if, surrounding the ideal library, we had small committee rooms, assembly halls, a café, or engineers' eating club. Many of the associations which perhaps could not coördinate in a general society could take part in some such arrangement.

In the discussion which Mr. Mershon referred to earlier in the evening questions came up, which he has already presented to you. Had there been but one society fifteen or twenty years ago, would there be so many members of engineering societies today as there are? Would there be the intensive interest that there is today? Would even the larger societies have been as large as they are, due to the accretion of the smaller societies, who, not having been taken in as societies but having found the advantages of combining, decided to place themselves on additional rolls, of making acquaintances, of coming in touch with engineers, of hearing little discussions here and there, of perhaps meeting far removed engineers and getting their views affecting their own ambitions and affecting their own researches and endeavors?

Albert Scheible, M. W. S. E.: In line with Mr. Chamberlain's remarks, it might be well to state that the Electric Club of Chicago has appointed a committee to work towards the possibility of a common engineering building for Chicago.

It has certainly been refreshing to hear Mr. Mershon, Mr. Reichmann, and others plead for a more hearty coöperation and coördination among our engineering societies, and to have Mr. Mershon dwell at such length upon one of the possibilities which can be gained by such a coördination as, for instance, in a common activity towards a commission for revision of our patent law practice. However, I think one of the impressions given out, perhaps unconsciously, ought not to go unchallenged; namely, the impression so often reflected in current rumors that a patent is nothing but a license for litigation. No doubt the electrical industry has been particularly

notorious in flagrant examples of abusing our patent system by costly litigation, court delays, and the like. However, I do not think that as engineering men who must know the extent to which progress is due to inventions, we should support the common fallacy that litigation is the common occurrence for inventors as including the patentee of the jimcrack device that never had any merit and never could have any. But even taking only those that have brought returns, while it would be difficult to get any fair average in the matter, my own experience, covering a contact with hundreds of patents in various lines that have actually brought returns for the inventors, implies that probably not over one per cent of these ever got into the courts. That observation has not been confined entirely to the electrical lines, I must admit, but it is so far from accord with some of the current impressions that these ought no longer to go unchallenged.

Peter Junkersfeld, M. W. S. E.: Mr. Mershon has paid us a compliment this evening by saying that in Chicago we, as engineers, act together more than in any of the other large centers of the country. It is very nice to hear that, but we must not feel flattered by it, because we have made only a very small start and we should realize, in that connection, what are our duties and what are our obligations.

One or two of the speakers have referred to the need of coöperation in a city like Chicago. I would like to go just a little further and say in a state like Illinois. When most of us were boys, Illinois was looked on as one of the great agricultural states of the Union. It is still one of the great agricultural states of the Union; but do we realize that we are living in an age when Illinois has progressed to a point where 49 per cent of the people living in the state get their livelihood from something connected with engineering interests? Do we realize, therefore, the need for coöperation in a constructive way? There are so many engineering societies, and their activities, while they are beneficial in many respects, should nevertheless be coördinated a little more than they are.

Mr. Chamberlain has pointed out some advantages of individual effort, but there should be organizing ability so as to maintain the benefits of that individual effort and at the same time secure some of the broader benefits of coöperative effort. In this state of Illinois, with 49 per cent of the people depending upon engineering interests, how much attention do engineers pay to legislative and constructive action, better sanitation, better transportation, public welfare, and things of that sort? We have heard that in Germany, for instance, the municipalities run their business like any other modern business undertaking would be run. A certain number of people—trustees or directors or whatever they may be called—have the matter in hand, and they go out and hire the best man they can find as the mayor of the city. In the state of Illinois,—in the United States, for that matter,—we are still very far behind in these re-

spects. There is much room for improvement, and there are no people better qualified and no people who fall farther behind in their obligations than the engineers; they should take a hand in this problem and do their full share toward solving it. In my judgment there is needed a centralization—call it a holding company or trust, if you wish—but some means by which the efforts of the many engineering and kindred organizations can be coördinated toward constructive action in the interest of the public welfare.

W. C. Bauer: I heartily agree with the last speaker. The complexity of life is such that we need individual effort and we need collective effort, and if the collective effort is put together and worked properly the individual effort will be worked out. We must be specialists nowadays to succeed, but the one who is an extreme specialist will never succeed, because our professions are beginning to overlap to such an extent that we must get the other man's vision, and only in a coöperative way can we do that.

I want to say something also on the patent situation. Among all the other good things we ought to have, I think one of the prime things is that we should increase the salaries of our examiners so that better men may be obtained for these positions,—men with better scientific training. In the last twelve years I have had occasion to act as expert on certain lines, and I have been surprised at the inaccuracy of the expressions of some of these examiners, and the time and money that must be wasted by the inventor to show the things that are on record; some of them are totally ignorant of even scientific facts which have been in the text-books for years and years.

We should also put forth every effort to bring about the means whereby infringement suits may be more quickly and economically settled.

D. W. Roper, M. W. S. E.: I have been much interested in the remarks that have been made this evening on coöperation, and I think it is a subject to which we can devote considerable attention.

As one allied subject on which coöperation has brought some good results, I might cite a little body of technical men here in the city representing various organizations, who have been acting in a private way for their respective corporations as an electrolysis commission. When they started in on that work they all had ideas of their own that were very radical, very rigid, and entirely opposed to each other, although possibly their ideas may have been no further apart than those of some of the engineers on other matters. But after each one had been given an opportunity to discuss the matter thoroughly, to state his views plainly and simply, to argue the matter at length, and eliminate all inaccuracies of statement, they found they were very close together. So that, after all of the useless discussion (we might say long discussion, it was not exactly useless), they found a common basis on which they could coöperate. That, of course, is of no particular interest to this meet-

ing as a technical point, but the principle of it is what we are after,—that sometimes our views are apparently very much opposed to each other, but when we get down to bedrock and analyze the situation we find we are very close together, and can harmonize our views and coöperate to the common end.

R. F. Schuchardt, M. W. S. E.: The thoughts I had on the matter of closer coöperation have already been so much better expressed by others that I will say nothing more on that subject. I am, however, prompted to add a word regarding the subject on which both Mr. Mershon and Mr. Junkersfeld touched, that is, the advisability of the engineer taking more active interest in civic affairs. The engineer ordinarily is an exceedingly busy man, and unless he has the opportunities made fairly easy for him, he is not likely to get out and interest himself in matters relating to the city's welfare. In that connection I would like to remind the engineers of Chicago of an opportunity (I am not trying to boost anything except the opportunity) that we all have of joining forces with other public spirited men in the work of the City Club. The City Club of Chicago has in its membership all sorts of professional and business men. Architects and lawyers particularly are very active there. But in a good deal of their work they need the trained mind of the engineer, and those of us who are interested in civic matters and want to do something for our city and our fellow men can find there a splendid opportunity.

A. Bement, M. W. S. E.: I would like to endorse and emphasize the remarks of Mr. Junkersfeld. I think the idea is so well put and so readily grasped that if we will keep it in mind we will get great good out of it. Mr. Schuchardt has also followed in the same line. In connection with the matter of the patent reform, it is something that we should keep in mind, for I believe there is an opportunity to better the situation to the benefit of all of us.

Wm. B. Jackson, M. W. S. E.: I wish to emphasize a thought that has not been referred to by the speakers this evening. Mr. Mershon has presented for our consideration two cases wherein it is evident that coöperation of engineering societies would be highly advantageous, since it is manifest that with coöperation among the appropriate engineering societies the problems involved would be solved with relative ease, and in the usual straightforward engineering fashion.

We have today a certain amount of coöperation between engineering societies, but such coöperation is not automatic, it is not a natural process. Coöperation in general between engineering societies is only entered into as a special order of business.

I contend that each one of our engineering societies should so arrange its organization and administration that it will enter into coöperation with the appropriate other societies as a matter of course in all those myriad of things wherein the combined power of two or more societies would be more effective than the unsup-

ported efforts of a single society. We should not be satisfied with coöperation in two or three or four special instances such as have been referred to this evening.

By such effective coöperation as I believe there should be between the various engineering societies, our engineering problems would be solved in the most economical and satisfactory manner. By engineering problems I mean all problems which affect engineering and the engineering profession.

There is another thought which is worthy of careful consideration: We have here in Chicago, as the representative of the engineering profession in the middle west and the west, the Western Society of Engineers, of which we are all justly proud. We also have a large membership in other engineering societies. Any move that can be made whereby the combined strength of the organization of our Western Society of Engineers and the organizations of the other engineering societies of the country will be united, is a distinct gain for the engineering profession as a whole, and cannot but strengthen the Western Society of Engineers, while at the same time benefiting the other participating societies.

I hope that everyone here will take home with him the thought and desire that there will be ever-increasing coöperation among engineers and engineering societies.

Chairman Goss: Mr. Mershon, have you any closing remarks?

Mr. Mershon: I think I have nothing further to say except to very warmly commend what Mr. Junkersfeld has said. He expressed, a great deal better than I did, a thought I had in mind; and I believe that the first and most important thing towards which we could direct our coöperative efforts would be that of inducing engineers to take the part which they should take, the place they should take, in the affairs of the community.

IN MEMORIAM

ARTHUR DEAN PAGE, M. W. S. E.

Died April 7, 1911.

Arthur Dean Page was born in Orono, Maine, February 28, 1866.

In June, 1886, at the age of twenty years, Mr. Page graduated from the Maine State College, completing a course in civil engineering. During the winter months prior to his graduation he was employed as a leveler on a preliminary survey of a fifty-mile road in Maine.

In the spring of 1887, Mr. Page journeyed to St. Cloud, Minn., entering the service of the city's engineering department, where

Memoir prepared by the following committee: A. Reichmann and Irvin L. Simmons.

October, 1913

he remained for three years, after which he began private practice in which he continued until 1895. Mr. Page then accepted a position with the Variety Iron Works at Cleveland, but remained only a short time, leaving in October, 1895, to accept a position in the bridge department of the Great Northern Railway Co. In November, 1896, he was made chief draftsman and subsequently bridge engineer.

Mr. Page entered the service of the C., R. I. & P. Ry. Co. March 1, 1903, as bridge engineer, and in 1906 was appointed principal assistant engineer, which position he was compelled to resign in March, 1909, on account of ill health.

The last important work upon which he was engaged while with the C., R. I. & P. Ry. was the designing of the Seventh Street Viaduct at Des Moines, Ia., which was built jointly by the C., R. I. & P. Ry., C. B. & Q. Ry., and Des Moines Union Ry. The designs for the C., R. I. & P. Ry. Co.'s Saline, Washita and Kaw River bridges were also prepared under Mr. Page's supervision. He also assisted in the designing of the first and largest steel grain elevators now located at Duluth and Buffalo.

After resigning his position with the C., R. I. & P. Ry. Co., Mr. Page opened an office in Chicago for private practice, which he maintained until the time of his death., April 7, 1911.

Mr. Page became an Active Member of this Society in March, 1907. He was a member of the American Railway Engineering Association and served on the committee of steel structures in preparing the specifications for railroad bridges. He was also a member of the Chicago Engineers' Club. A widow and one son survive him.

OSCAR SANNE, M. W. S. E.

Died April 4, 1913.

Oscar Sanne, C. E., died after a short illness at his home, Glen Ellyn, Illinois, Friday, April 4, 1913.

He was born on the 20th day of November, 1855, in Hamburg, Germany, where his father, Louis Sanne, was a well-known piano manufacturer.

He received his technical education at the Polytechnic High School of Carlsruhe, Germany, and came to this country in the year 1882. His first position was in the bridge department of the West Shore Buffalo Ry. From 1883 to 1885 he was with the Edge Moor Iron Works as assistant engineer. After filling several similar positions, he entered the services of the Chicago, Milwaukee & St. Paul Ry. as assistant bridge engineer.

On March 14, 1889, Mr. Sanne was married to Miss Hertha Anneke, of Milwaukee, who survives him.

Memoir prepared by the following committee: Alexander von Babo and Theodor Rall.

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In the year 1890 he opened an office of his own at Milwaukee as consulting engineer. His principal practice was in connection with bridge engineering, and a number of bridges in the parks of Milwaukee will give testimony for many years to come of his ability as a designing engineer, fully considering the principle of art in engineering works.

In the year 1898 he became an Active Member of the Western Society of Engineers and presented three papers before the Society, one in August, 1898, Park Bridges, one in April, 1899, Some Hints on Bridge Designing, and one in February, 1904, Graphical Calculation of Flange Stresses in Girders and Trusses.

In consequence of poor health he gave up his private practice in the year 1898 and after an extended rest he went to New York, where he took a position with the Metropolitan Elevated Railway Co. as assistant engineer during the reconstruction and strengthening of the elevated railway structure of that company. In this position he had an opportunity to show his ability in the way of combining art with usefulness in designing engineering structures.

In the year 1906 he entered the bridge department of the City of Chicago as a structural and designing engineer, which position he held to November, 1912. In his service with the City of Chicago he worked on a number of bridges, calculating and designing. As he was a close student of the artistic element of bridge designing, nothing gave him more delight than to have an opportunity to exercise his talent in this direction. When the element of art became a factor in designing bridges for Chicago, he was only too anxious to take up this task. One of his first endeavors in this direction was in connection with the architectural treatment of the abutment and operating houses for the new Washington Street Bridge, and though his original design was superseded by still more elaborated plans, it was an important first step in the development of the architectural treatment of bascule bridges for Chicago. Two pleasing reinforced concrete arch bridges, both over the Illinois and Michigan Canal, one at South Western Avenue and the other at South Kedzie Avenue, were also designed by him. These bridges will remain as tokens of his artistic talent.

Mr. Sanne was a man of general culture, interested in science, art, literature, and music. He was a born optimist and had a kind and cheerful word for everyone. Those who knew him esteemed his friendship and will always remember him as a man of pure and noble mind.

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Regular Meeting, October 6, 1913.

A regular meeting of the Society (No. 833) was held Monday evening, October 6, 1913. The meeting was called to order at 8:15 p. m. by President Reichmann, with about 80 members and guests in attendance. The minutes of the previous meetings were not read, as they had been published in the Journal.

Mr. H. B. Kirkpatrick, M. W. S. E., read the paper by Mr. T. V. Salt, M. W. S. E., on "The Manufacture of By-Product Coke," because of the absence of the author. Discussion followed from Messrs. W. L. Abbott, A. Bement, R. A. Traverse and F. W. DeWolf, with a closure from Mr. Kirkpatrick.

Meeting adjourned about 10 p. m.

Extra Meeting, October 13, 1913.

An extra meeting of the Society (No. 834), in the interests of the Bridge and Structural Section, was held Monday evening, October 13, 1913. The meeting was called to order at 8:15 p. m., Mr. J. H. Prior, vice-chairman of the Section, presiding, with about 80 members and guests in attendance. The chairman introduced Mr. Charles Hodgdon, Architect, who read his paper on "The Grand Stand of the Athletic Field of the University of Chicago." This was illustrated by a number of lantern slides, showing this reinforced concrete structure during construction, and after completion. Discussion followed from Messrs. J. H. Prior, J. F. Hayford, Ernest McCullough, W. C. Armstrong, I. F. Stern, W. H. Warner, L. J. Mensch, J. F. Brown, W. F. Smith, and A. Reichmann, with explanations and replies from Mr. Hodgdon.

In conclusion, Mr. Stern moved a vote of thanks to Mr. Hodgdon for his courtesy in preparing and presenting this interesting paper to the Society, which was carried.

Meeting adjourned about 9:15 p. m.

Extra Meeting, October 20, 1913.

An extra meeting of the Society (No. 835), in the interest of the Hydraulic Sanitary and Municipal Section, was held Monday evening, October 20, 1913.

The meeting was called to order at 8:20 p. m., Mr. Langdon Pearse, chairman, with about 50 members and guests in attendance. There being no business before the meeting, the chairman introduced Dr. Edward Bartow, of the Illinois State Water Survey, Urbana, Ill., who read his paper (prepared jointly with Mr. Paul Hansen), on "Water Filtration in Illinois." The paper was illustrated by a number of lantern slides. Mr. Langdon Pearse followed with a description of the filtration plant for Evanston, Ill., now under construction and lately visited by a number of the members of the Society. Mr. James Macdonald described some details of the concrete construction of the Evanston plant, for which he is the contractor. Further discussion followed from Messrs. L. O. Jahn, of Moline; F. L. Stone, Paul Hansen, John Dennison, W. W. DeBerard, G. M. Mayer, L. K. Sherman, F. W. DeWolf, with replies and explanations from Dr. Bartow and the chairman.

Meeting adjourned at 9:50 p. m.

J. H. WARDER, Secretary.

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BOOK REVIEWS

The Books Reviewed Are in the Library of This Society.

ELECTRICAL ENGINEER'S POCKET BOOK. A Hand-book of Useful Data for Electricians and Electrical Engineers. By Horatio A. Foster. With the Collaboration of Eminent Specialists. Seventh Edition. Revised, New York, D. Van Nostrand Co., 1913. Flexible leather binding; 1,599 pages (including index); 4½ by 7 in. Many tables, diagrams and illustrations; thumb index in the margin. Price, \$5.00.

This hand-book has been well known for several years, and earlier copyright dating 1902, and in the several editions since then, the book has been revised and materially enlarged and improved. The list of contributors includes some notable names as Prof. Samuel Sheldon, Dr. Harold Pender, Cecil P. Poole, E. B. Raymond, Dr. C. H. Sharp, Dr. F. A. C. Perrine, Lamar Lyndon, Profs. F. B. Crocker and M. Arendt, W. Wallace Christie, and others. The substance of the book is divided into a number of sections, as for instance: Symbols, Units, and Instruments, Measurements, Magnetic Properties of Iron, Electromagnets, Properties of Wires and Cables, Properties and Dimension of Conductors, Underground Conduits and Construction, Cable Testing, D. C. Dynamos and Motors, and A. C. Machines, Static Transformers, Electric Lighting, and Illuminating Engineering, Electric Railways, Transmission of Power, Storage Batteries, Switchboards, Telegraphy, Telephony, Electricity in the Army and Electricity in the Navy, Electro-Chemistry and Electro-Metallurgy, Electric Heating, Cooking and Welding, Lighting Conductors, Foundations and Structural Materials, Steam and Water Power, Shafting, Pulleys, Belting and Rope Driving, etc., etc.

The table of contents, is very full and complete, divided and enumerated under sections, as noted above. This table in connection with the marginal thumb index and the 65 pages of Index, should make it very easy to find any subject desired. As is proper in such a book as this, the Standardization Rules of the A. I. E. E., approved by the Board of Directors, June 27, 1911, is printed at length, covering 29 pages. The subject of Electric Lighting, revised by Dr. C. H. Sharp, occupies some 56 pages, and is full of information on the different illuminating devices, as incandescent lamps of various sorts, Arc lamps, open, enclosed and flaming, search lights, arc lamp carbons, Street lamps and street lighting, etc. Some 25 pages are devoted to Illuminating Engineering, in its various aspects. The subject of Telephony, occupying some 50 pages has been revised by Mr. J. Lloyd Wayne, 3d. Telegraphy, revised by Charles Thom, occupies 15 pages, and is followed by a chapter of 14 pages on Wireless Telegraphy, revised by F. K. Vreeland. The book is well printed, the type face though necessarily small, is clear, the illustrations are well made, and the paper though thin, is fairly opaque so there is no trouble in reading the text. The book is a valuable, even an almost indispensable addition to an engineer's library, if he is at all concerned in electrical matters.

PLANS OF GRAIN ELEVATORS. The Grain Dealers' Journal. Mr. Chas. E. Clark, Ed.; 3d Edition; Chicago, 1913; 9 by 12 in.; 398 pages of illustrated text, with over 1,200 illustrations from line drawings or photographs. Cloth bound. Price, \$5.00.

This is an interesting and valuable book on this special subject of grain elevators. Many different plans are shown, varying in size and arrangement for handling and storing grain, to suit special or local condition.

There is also shown the mistakes made by those who are not qualified in the designing and construction of elevators, which become all too frequently, the victims of wrecks or fire loss. The earlier design of grain elevators, and which may still be used in small installations, consists of a set of bins, of wooden construction, but which too frequently were not strong enough to hold against the internal pressure, when loaded with grain.

The next advance was of wood crib work, usually plank of commercial sizes, laid on the flat, one on top of another, and spiked together, breaking joints, and the interior partitions of the same construction, built up with

and tied to the outer walls. The planks used were generally 2 in. thick and of varying widths, say from 14 to 16 in. at the bottom, reduced to 6 or even 4 in. wide at the top of the walls. Such structures were frequently covered on the outside with thin sheet iron, zinc coated, or slate covered, with lap joints, as in a roof. The next step in advance is believed to have been the use of steel or iron plates in which case the bins were cylindrical in plan. The spaces between the cylinders, was also used for storage. With such construction, and material, strength against internal pressure can be readily secured, and with the further advantage that the space occupied by the walls of the bins would be a minimum—less than with any other material. Other material used for the bin walls was brick, tile and concrete, but with such material it was necessary to reinforce the walls, against the variable stresses of the contained grain.

In the book above noted, the illustrations show many examples of these different modes of construction. There is much more about an elevator than simply an aggregate of containing bins. Provisions must be made for machinery for receiving, handling, elevating, distributing, and withdrawing the grain for shipping, and these operations are further modified by the location and object of the elevator whether operated in connection with railroads or boat service, for receiving or shipping. Many of the plans in the books are from actual installations showing the location of the elevator for receiving and shipping the grain by either or both, cars and boats. A study of the book would be valuable to anyone interested in a projected elevator. But anyone who thinks of building an elevator and operating it as a business, should by all means secure expert engineering advice and planning, if he wishes to be successful in the business. Interesting and valuable as is this book, it alone will not give all the knowledge necessary for the plans and designs for a grain elevator that will earn a suitable return on its cost.

DESCRIPTIVE GEOMETRY. By Adam V. Millar and Edward S. Maclin, Professor and Instructor of Drawing, University of Wisconsin. New York, 1913. McGraw-Hill Book Co. 131 pages, $5\frac{1}{4}$ by $7\frac{3}{4}$ in.; 78 figures in the text; cloth bound.

This small text-book seems to possess advantages over corresponding text-books used by an earlier generation of students. It is planned with the thought "to make the subject easier for the student, to help him to visualize magnitudes in space, and to present the subject more nearly in accord with commercial practice." Chapter I, of 20 pages, enunciates "First Principles" of projection of points, lines, planes, etc. The elementary principles of point, straight line, and plane, is the subject of Chapter II, and consists of 32 pages of text and problem. In Chapter III, of 20 pages, is considered the application of these elementary principles as applied to Shades and Shadows and the development and intersection of surfaces. Chapters IV, V and VI take up the subjects of curved lines and surfaces, their sections and developments. This is covered in 55 pages. The illustrations are clear and well presented. The problems throughout the text seem to be well selected, and a careful study of the book, with a comprehensive absorption of the matter as set forth, should be a great benefit to the student who desires to be a thorough draughtsman.

ENGINEERING TABLES AND DATA. By W. W. F. Pullen, M. I. Mech. E.; Assoc. M. Inst. C. E. Scientific Publishing Co., Manchester, England. 3rd ed.; flexible cloth; $8\frac{1}{2}$ by $5\frac{1}{2}$ in.; pp. 68. Price $1\frac{1}{6}$ net.

The author states in the Preface that "this little collection of tables and data has been compiled to supply a want which has been experienced in the laboratory, the testing shop and in engineering educational work generally. The steam table has been entirely revised, and now represents the results of the most recent researches. The compiler has received much valuable aid in the construction of this table from Mr. Gilbert Farrar, B. Sc., to whom he desires to offer his thanks. The table is given in both Fahrenheit and Centigrade units."

The Table of Contents is as follows: Circular Measure of Angles. Natural Sines, Cosines, Tangents and Cotangents. Common Logarithms and Antilogarithms. Hyperbolic or Napierian Logarithms. Hyperbolic Functions. Measurement and Conversion Factors. Water Density Table. Thermometer Conversion Tables. Specific Heat, Coefficient of Expansion, Density, etc., Table. Table Relating to Fuel and Combustion. Steam Tables. Fahrenheit and Centigrade Units. Steam Dryness Chart. Superheated Steam. Thermal Conductivity. SO_2 Chart. Ammonia Chart. CO_2 Chart. Mensuration. Mathematical Data. Standard Differential Coefficients. Standard Integrals. Differential Equations.

The paper is of a good firm quality and the tables and formulæ are in clear type, easily read.

The former edition as well as this third edition are on the shelves of the library of this Society.

LIBRARY NOTES

The Library Committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts, the following publications have been received:

NEW BOOKS.

Norman W. Henley Publishing Co.:

Locomotive Boiler Construction, F. B. Kleinhaus. Cloth.

McGraw-Hill Book Co.:

Overhead Electric Power Transmission, Alfred Still. Cloth.

Safety First, George Bradshaw. Paper.

Laboratory Manual of Testing Materials, Hatt and Scofield. Cloth.

Hydraulic Turbines, R. L. Daugherty. Cloth.

Design of Plate Girders, L. E. Moore. Cloth.

City Club of Chicago:

The Railway Terminal Problem of Chicago. Pam.

The Macmillan Company:

Alternating Currents and Alternating Current Machinery, D. C. and John P. Jackson. Cloth.

American Railroad Economics, A. M. Sakolski. Cloth.

Mechanics and Heat, J. Duncan. Cloth.

Rochester, N. Y., City Engineer:

Report on Sewage Disposal System of Rochester. Cloth.

Bureau of Railway News and Statistics:

The Railway Library, 1912, Slason Thompson. Cloth.

C. L. Strobel, M. W. S. E.:

The Railway Terminal Situation, Chicago Plan Commission. Folio.

San Diego Chamber of Commerce:

The Climate and Weather of San Diego, Cal. Cloth.

Toronto, Canada:

Building By-Law, City of Toronto, 1913. Pam.

E. E. R. Tratman, M. W. S. E.:

Cours de Mécanique, L. Guillot, Vol. III. Cloth.

Cleveland, Ohio, Building Department:

Administrative Sections of the Building Code of Cleveland. Pam.

Clinton Wire Cloth Co.:

Some Tests and Data on Fireproof Floor Construction. Pam.

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MISCELLANEOUS GIFTS.

- E. E. R. Tratman, M. W. S. E.:
 Proceedings Michigan Engineering Society, 1912. Cloth.
 Proceedings, Fifth Annual Convention International Railway Fuel Association. Pam.
 Administration Report of Railways in India, 1912. Paper folio.
 Report of Chief Commissioner New South Wales Government Railways and Tramways, June 30, 1913. Paper folio.
- Onward Bates, M. W. S. E.:
 Proceedings, Society for the Promotion of Engineering Education. Vol. XX, No. 2. Cloth.
 Report of Illinois Highway Commission, 1910-11-12. Paper.
 Proceedings American Road Congress, 1912. Part II. Paper.
- Sanitary District of Chicago:
 Proceedings of Trustees, 1912. Cloth.
 Annual Message of President, 1913. Leather.
- Canada Commission of Conservation:
 Report of Fourth Annual Meeting, 1913. Cloth.
- C. L. Strobel, M. W. S. E.:
 Report of Illinois Highway Commission, 1910-11-12. Paper.
 Good Roads Year Book, 1912. Cloth.

EXCHANGES.

- Engineers' Club of Philadelphia:
 Directory, 1913. Leather.
- Canadian Society of Civil Engineers:
 Transactions, Vol. 26, Part II, 1912. Paper.
- Boston Society of Civil Engineers:
 Year Book, 1913-14. Pam.
- Brooklyn Engineers' Club:
 Proceedings, 1912. Cloth.
- American Society for Testing Materials:
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MEMBERSHIP

Additions.

Holzingar, Joseph O., Chicago.....	Associate Member
McIntosh, Alexander H., Chicago.....	Associate Member
Mertz, Herbert, Chicago.....	Junior Member
Myler, Thomas K., Chicago.....	Junior Member
Pravdiza, Arthur T., Chicago, transferred from Junior to	Associate Member
Sturges, Frederic D., Evanston, Ill.....	Junior Member
Warner, William H., Chicago, transferred from Junior to	Associate Member

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THE ADAPTATION OF BOILER FURNACES TO AVAILABLE COALS

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When the writers of this paper went to South Carolina three years ago to take up work as fuel engineers of the Clinchfield Fuel Company, they found three types of steam boilers in general use:

(a) Water-tube boilers with tubes inclined slightly from the horizontal, having transverse gas baffles such as make the gases cross the tubes up, down and up (three passes);

(b) Horizontal return tubulars;

(c) Vertical water-tube boilers with upper and lower drums, furnaces of the Dutch-oven type, level with and in front of the lower drums, the gas paths being in and parallel to the tubes, so that the gases depart through holes in the upper drums.

Work has been done in modifying the combustion spaces of all three types of boiler, but inasmuch as the time is limited, this paper will be devoted to type (a) described above, although the results obtained by modifying the combustion spaces of this type are not more remarkable than those obtained by modifying the others.

It is ordinarily advisable to let well enough alone, wherefore it is in order to inquire here why any changes were advised. A glance at Fig. 1 will show that the states of Virginia, North Carolina, South Carolina, Georgia, and Alabama must draw their coals from the southern fields, beginning with the New River District in West Virginia and running southwest. (The shaded areas are coal measures more or less endowed with workable seams.) The coal-originating roads are shown only from the coal fields to their junction points with other roads, where the cars are turned over by the initial carriers. Coal from the New River District, served by the Chesapeake & Ohio Railway, moves on the same freight rates to all points as does coal from the Pocahontas District, served by the Norfolk & Western Railway. Coal from the Clinch Valley District in southwestern Virginia, at the (present) upper end of the Carolina, Clinchfield & Ohio Railway, comes into competition with the West Virginia coals (New River and Pocahontas) in North Carolina; therefore the heavy broken line is put on the

map and labeled "Line of Equal Freight Rates." Immediately north of this line the West Virginia coals have rates 10c per short

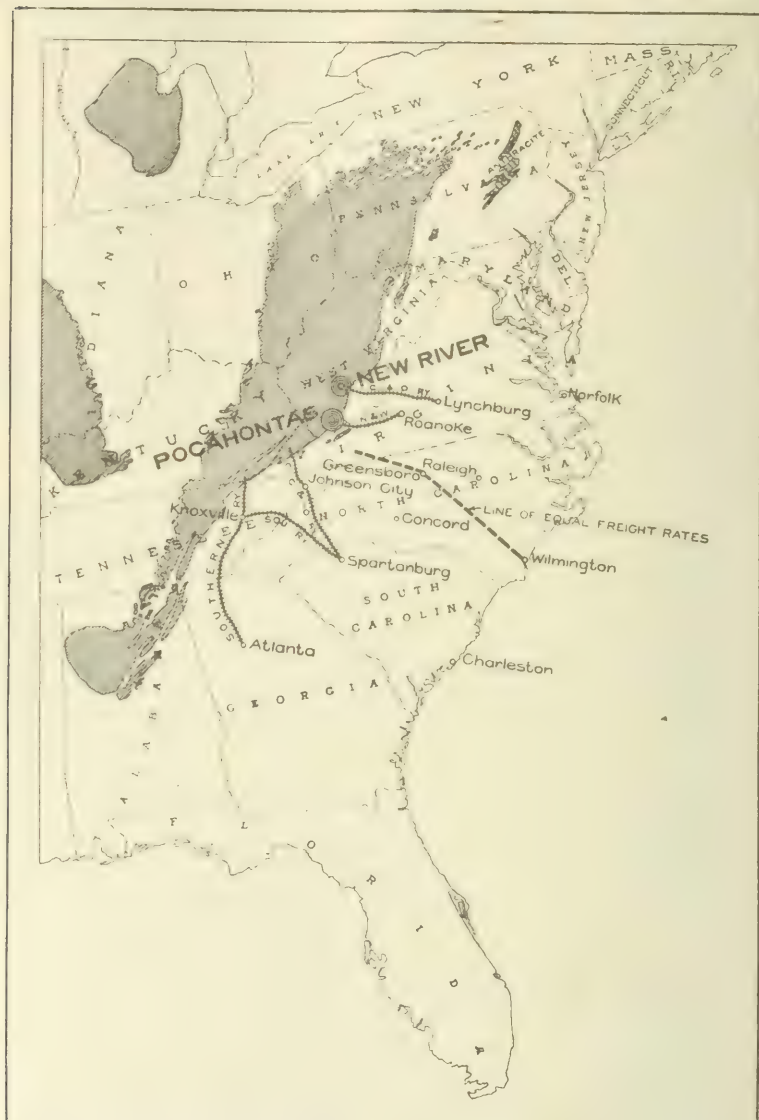


Fig. 1.—Map of Coal Field.

ton under the Clinch Valley coals, and south of this line, vice versa. (As a matter of fact, this line is a narrow band.) Toward

the southwest the differential against West Virginia coals increases, until at Atlanta, Ga., it is 105c. It is therefore evident that most of the states of the Old South find it to their advantage to burn coals carrying the lower freight rates, and this situation will remain permanent for reasons of geographical distance, especially since the heat values of all the coals concerned are substantially the same, and all high.*

The coals of the New River and Pocahontas fields differ considerably from those of Virginia, and more still from those to the southwest, in that the first-mentioned contain about 20% volatile matter and the remaining about 30% and more. In contradistinction to the coals of the Eastern Interior and adjacent fields, the oxygen content is low, so that the volatile combustibles run high. It is not necessary to explain to this Society that the coals high in volatile matter and low in oxygen need plenty of room in which to burn, but that the very high rate of combustion obtainable on a comparatively small grate surface renders such coals very desirable for working boiler investments at a high rate. Another way of putting the matter is to say that the fixed carbon residuums of all coals burn on grates at about the same rates under the same conditions of draft, etc., and that any burning of volatile matter in the space above and beyond the fuel-bed is so much additional capacity or increased rate of steam production. There is no need, either, to enter into a discussion of the reasons for expecting a higher efficiency from coal to steam due to allowing more room for combustion.

It is not claimed that the tests described herein are of any radically new baffling, but so far as the writers know, there are not extant many sets of tests giving comparative performances of the same boiler baffled in three different ways; this paper shows conclusively the advantage of giving gases more room in which to burn.

Attention is specially called to the fact that the steaming capacity of the boiler was not decreased by the gas paths being of higher resistance than that of the original baffling.

SPECIFIC DESCRIPTION OF TESTS.

OBJECT.

The object of the tests was to determine whether by baffling the boiler horizontally, thereby obtaining a larger combustion space in the furnace, high volatile coal could be burned with good results, and at the same time to determine whether, with the horizontal baffle, Pocahontas coal could be burned as economically as with the standard vertical baffle.

*It may be well to say that the companies with which the writers are associated handle large quantities of coals from all the fields here discussed, and others, too.

THE COALS.

Two kinds of coal were used in the tests, Pocahontas and Clinchfield. The Pocahontas coal was shipped by the West Virginia Pocahontas Coal Sales Corporation from its Leckie mine, located in Mercer County on the Norfolk and Western Railway.

The Clinchfield coal was shipped by the Clinchfield Coal Corporation. The first carload came from mine No. 5, Dante, Va., and the second and third carloads came from the Crane's Nest mine. All coal used in the tests was straight run-of-mine.

SCOPE OF TESTS.

The tests were made in three series:

The first series, consisting of seven tests, was made with the boiler baffled vertically as it was installed by the maker. The lo-

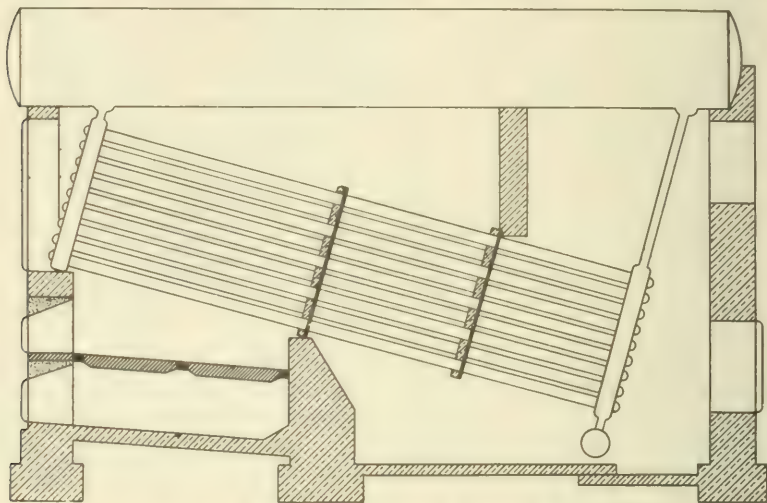


Fig. 2.—Boiler as Originally Set and Baffled.

cation of the baffles and the principal features of the boiler are shown in Fig. 2. Four of this series of tests were made with Clinchfield coal from a Dante mine, and three with Pocahontas coal.

The second series consisted of seven tests made with the same boiler baffled horizontally in such a way that the space beyond the bridge wall was used as a combustion chamber, the burning gases passing lengthwise, first under the boiler and then twice among the tubes and out through the breeching. The heating surface of the drums was not used with this baffling. The arrangement of the baffles and the path of the gases are shown in Figs. 3 and 4. Three tests of this series were made with Pocahontas coal and four with Clinchfield coal from the Crane's Nest mine.

The third series, consisting of five tests, was made with the same boiler baffled horizontally in such a way that the gases passed

lengthwise under the boiler as in the second series, then three times among the tubes and finally under the steam drums and out through the breeching. The arrangement of the baffles and the path of

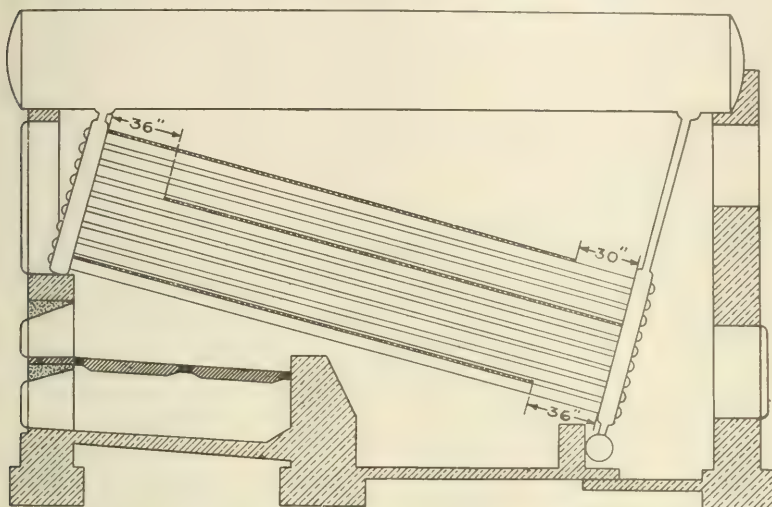


Fig. 3.—Two Pass Horizontal Baffling.

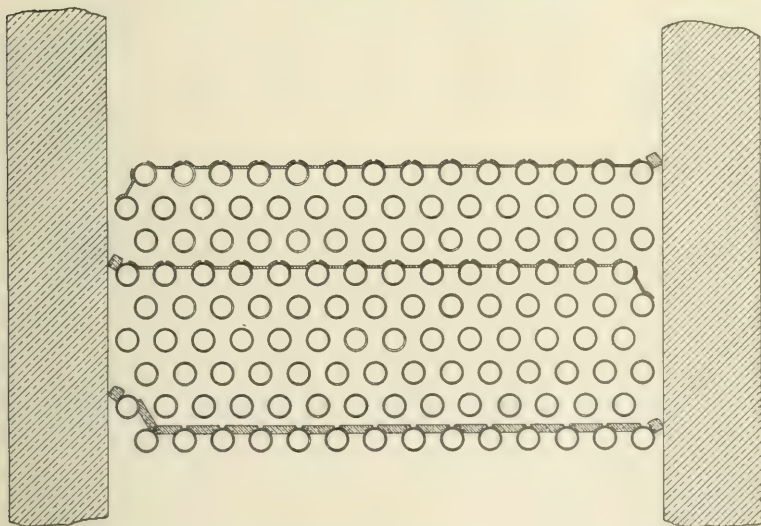


Fig. 4.—Cross Section—Two Pass Horizontal Baffling.

gases are shown in Figs. 5 and 6. Three tests of this series were made with Clinchfield coal from the Crane's Nest mine, and two with Pocahontas coal.

METHOD OF CONDUCTING THE TESTS.

All nineteen tests were run under the actual operating conditions of the plant. Usually the tests were begun in the morning when the work at the mill was started and were run through the

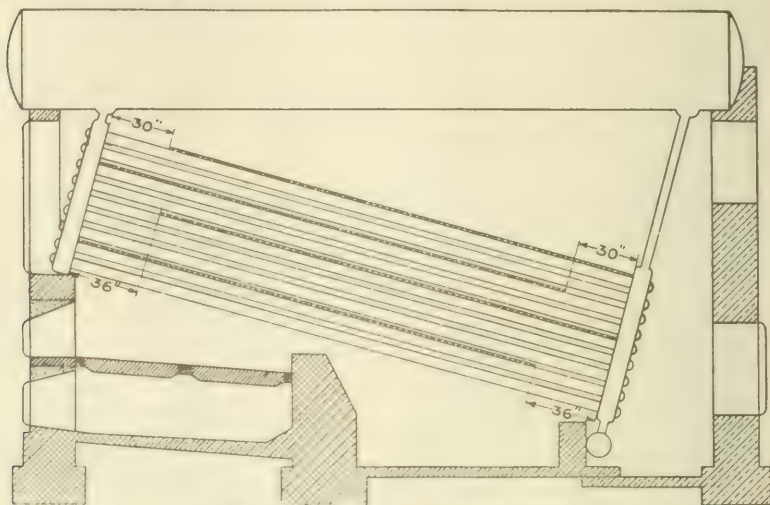


Fig. 5.—Three Pass Horizontal Baffling.

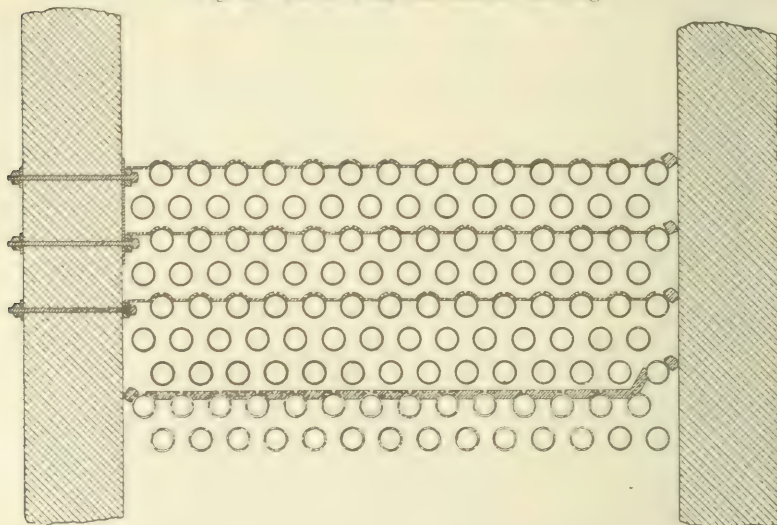


Fig. 6.—Cross Section—Three Pass Baffling.

day (with a 30-minute stop at noon) until 6 o'clock in the evening, when the mill was shut down. At noon the main engine was stopped and there was no demand for steam for about 30 minutes.

During this period the chimney damper was closed. During the tests all coal burned was carefully weighed in a wheelbarrow. The water used in the boiler was measured in a special tank. The measured water was run into a suction tank from which it was fed with an injector into the test boiler as it was needed. The temperature of the feed water was determined in the measuring tank, inasmuch as the water in the suction tank was always hotter on account of the overflow from the injector. The temperature of the outside and inside air, as well as that of the escaping flue gases, was determined. In most of the tests samples of flue gases were collected and analyzed in an Orsat apparatus. Records of steam pressure and drafts were also kept. These records made it possible to compute the results accurately and express them in pounds of water evaporated per pound of coal.

PERSONNEL.

The boiler tests were made under the personal direction of the writer by the members of the engineering department of the Clinchfield Fuel Company.

The same men changed the baffles of the boiler.

SUMMARY OF RESULTS.

The following table gives a summary of the results of the tests:

	Standard Original Baffling		Boiler with two Horizontal Passes		Boiler with three Horizontal Passes	
	Pocahontas Coal Average of four tests	Clinchfield Coal Average of three tests	Pocahontas Coal Average of four tests	Clinchfield Coal Average of three tests	Pocahontas Coal Average of two tests	Clinchfield Coal Average of three tests
Pounds of water evaporated under actual conditions per pound of coal as fired	7.95	7.49	8.54	8.18	8.83†	8.52
Equivalent evaporation per pound of coal as fired...	9.42	8.90	9.92	9.61	10.33†	9.97
Average h. p. developed....	320	285	335	357	303*	298*
Maximum h. p. developed..	341	297	355	365	317	311
B. t. u. per lb. of dry coal	14,828	14,122	15,050	13,801	14,731	13,750
Ash, per cent	4.9	7.9	4.72	10.26	5.5	9.85
Approximate efficiency of boiler and furnace.....	61.3	60.9	63.6	67.2	67.7†	69.9

*Note: On the test with three horizontal passes, higher capacity could have been developed but the feed water was too hot and the injector would not feed it fast enough into the boiler.

†On the two tests with Pocahontas coal the feed water became so hot in the afternoon that water could not be fed into the boiler, and the tests had to be stopped before the fuel bed could be burned down to the same level as it was when the tests were started. Consequently the efficiency appears to be lower than it really was.

CONCLUSIONS.

The preceding summary of results shows conclusively that much better results can be obtained with Clinchfield coal when the boiler is baffled horizontally. There is also a marked improvement in the results in favor of the horizontal baffling when Pocahontas coal is used as fuel. The horizontal three-pass baffling gives the highest evaporation; the horizontal two-pass baffling gives the highest horse power developed during tests.

With the two-pass horizontal baffling better evaporation and higher horse power can be obtained with Clinchfield than with Pocahontas coal and the standard vertical baffling.

DETAILED DESCRIPTION OF METHODS.

STARTING AND STOPPING THE TESTS.

In starting and stopping the tests, a modification of the "alternate method" recommended by the American Society of Mechanical Engineers was used. The fire was cleaned either early in the evening or at about 4 o'clock in the morning; it was then banked and left in that condition until about 5:30 o'clock. At that time the banked coal was spread over the grate and more fresh coal was fired two or three times. Before starting a test the firing was suspended for 15 or 20 minutes so as to have a thin uniform layer of hot coke on the grate. The test was usually started 15 to 30 minutes past 6 o'clock.

When starting the tests the fuel-bed was carefully leveled and its thickness measured by dipping into it the prongs of the rake and noting to what depth the prongs sank into the fuel. The thickness of the fuel-bed when the test was started was usually about 2 in. or even less. The object of starting with a thin fire was to reduce the error in estimating the thickness of the fuel-bed. The height of water in the gauge glass and in the suction tank was measured and recorded to within $\frac{1}{4}$ in.

When closing the tests the fire was burned down to the same thickness as it was when the test was started. The thickness in this case was measured above the layer of clinker and ash. Also at this time the water in the gauge glass was as nearly as practicable at the same height as when the test was started. In case the fuel-bed was burned down to the right thickness before the water in the gauge could be brought to the same level as it was at the start, the test was closed and corrections were made for the difference in water level. It was found from the dimensions of the two steam drums that at the level of the glass water gauge, the drums held 550 lb. of water per inch of height as shown in the gauge glass. The test was closed about the same time the mill engine was shut down. The fireman stopped firing the test boiler at the same time he would have stopped if no test were being run.

The fire was not cleaned before closing the test for two reasons, namely: In the regular operation of the plant the fires were

never cleaned before the end of the day's run, and it was desirable to make the tests under as nearly regular operating condition as possible. It would have been difficult to keep up the steam pressure if the fire had been cleaned while the mill engine was running.

WEIGHING THE COAL.

The coal was weighed in wheelbarrow loads of 300 lb. A steel-top wheelbarrow was loaded and placed on a platform scale,

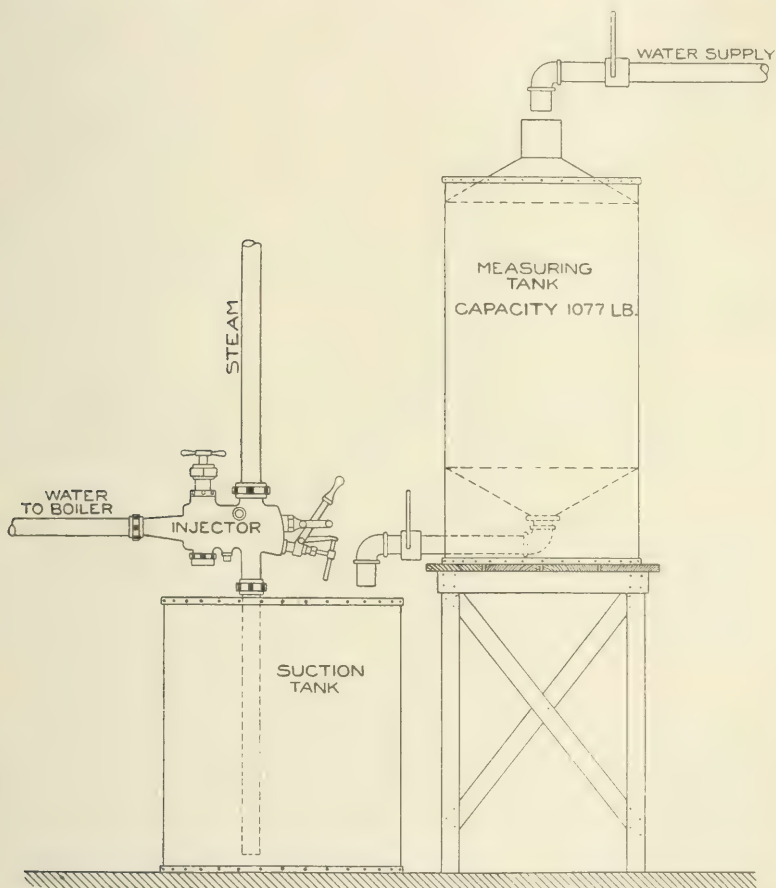


Fig. 7.—Measuring the Water Supply.

and enough coal added to it or taken off so that the net weight of the coal was exactly 300 lb. Every time the wheelbarrow was dumped, the weight of the coal, as well as the time of dumping the wheelbarrow, was recorded. The object of recording the time

was to eliminate the possibility of recording a wheelbarrowful twice, or of not recording it at all.

MEASURING THE FEED WATER.

The water fed into the test boiler was measured in a specially-constructed tank, shown in Fig. 7. The latter had a funnel-shaped bottom which permitted a quick and thorough emptying. The top of the tank was contracted into a narrow neck, which feature greatly reduced any error arising from a possible difference of water level. The body of the tank was 30 in. in diameter and about 4 ft. high. The capacity of the tank was determined, by actual weighing, to be 1,077 lb. of water at 75 deg. F. This figure was used in the computation of all 19 tests. The measured water was run into a suction tank which was 3 ft. in diameter and 4 ft. high. From the suction tank the water was fed into the boiler with an injector. Every time the measuring tank was emptied the weight of water and the time of emptying were recorded. During each test the blow-off piping of the test boiler was disconnected and the amount of leakage measured. No water could get into the boiler except through the injector.

FEED-WATER TEMPERATURE.

The temperature of the feed water was read about once in every hour. It was measured by inserting a mercury thermometer into the stream of water when emptying the measuring tank.

FLUE-GAS TEMPERATURE.

The flue-gas temperature was measured with a high-reading mercury thermometer which was inserted into the top of the steel breeching connecting the boiler setting with the stack. The breeching was 4 ft. wide by 4 ft. deep. The bulb of the thermometer was located about 1 ft. from the top and equally distant from the two sides.

DRAFT MEASUREMENTS.

Measurements of draft in the breeching and over the fire were made at intervals of one hour with a draft gauge consisting of a U-shaped glass tube filled with kerosene. Kerosene was used in the tube because the inner surface of the tube remains moist, so that the height of the kerosene columns is more readily changed with differences in the draft. The specific gravity of the kerosene was about 0.78. The draft in the breeching was measured by inserting a small copper tube connected to the draft gauge into a small hole made in the top of the breeching. This hole was 5/16 in. in diameter and was located within 2 in. of the one used for measuring the temperature of the flue gases. Both holes were about 3 ft. from the boiler and about 5 ft. from the junction of the breeching with the stack. Over the fire the draft was measured by inserting the small copper tube into the furnace through a hole in the firing door.

FLUE-GAS ANALYSIS.

During the most of the test, samples of the flue-gas were collected and analyzed for CO_2 with an Orsat apparatus. Some of these samples were also analyzed for O_2 and CO . The gas samples were not continuous but "grab" samples; that is, the collection of each sample covered a period of only about 30 seconds. The samples were collected 30 minutes to one hour apart. The same copper tube inserted in the same hole in the breeching was used for collecting the flue-gas sample as was used in measuring the draft.

STEAM PRESSURE.

Steam pressure was read off the regular pressure gauge on the boiler about every hour. This steam gauge was approximately correct, and the pressure remained nearly constant during each test.

THE WEIGHT OF ASHES.

Soon after starting each test the ash pit was cleaned and the fire was run all day without removing any clinker from the furnace or any ashes from the ash pit. About half an hour before closing the test the ash from the ash pit was removed, weighed, and charged to the test. About 10 minutes after closing the test, the fire was cleaned and all the refuse pulled out from the furnace was weighed and also charged to the test. Ordinarily when no test was run the fire was not cleaned until about 4 o'clock in the morning.

ANALYSIS OF COAL.

As the coal used in the tests was weighed, a shovelful was taken from each wheelbarrow for a sample. The sample thus collected was carefully quartered and sent to a chemical laboratory for analysis. The average of these analyses for each series of tests is given in the table of results.

DESCRIPTION OF BOILER.

The boiler used in the tests was one of the three similar boilers in the plant. It was located at the south end of the boiler plant and designated as boiler No. 3. It was set by itself and provided with its own steel stack. The stack was placed outside of the boiler room on a brick foundation. The boiler setting was connected to the stack with a steel horizontal breeching 4 by 4 ft. in cross section. The furnace was equipped with a rocking grate.

PRINCIPAL DIMENSIONS OF BOILER AND FURNACE.

Type of Boiler.....	horizontal water tube
Capacity as rated by builders, boiler horse power.....	250
Number of horizontal rows of tubes.....	9
Number of tubes in each horizontal row.....	14
Total number of tubes in boiler.....	126

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Diameter of tubes, inches.....	4
Length of tubes, feet.....	18
Number of steam drums.....	2
Length of steam drums, feet	20.3
Diameter of steam drums, inches.....	36
Water heating surface of tubes, square feet.....	2381
Approximate water heating surface of drums, square feet.....	165

Furnace:

Width of grate—inches.....	96
Depth of grate—inches	72
Height of bridge-wall—inches.....	20

Kind of Grate shaking

Approximate width of air spaces—inches	3½
Approximate percentage of air spaces	30
Total grate area, sq. ft.	48

Stack:

Diameter of steel stack—inches	48
Height of stack—feet	80
Approximate length of steel breeching—feet	10
Size of steel breeching—feet	4x4

Gas Passages:

Length of gas path among boiler tubes with standard three-pass vertical baffling—feet	13.5
Length of gas path among boiler tubes with two-pass horizontal baffling—feet	30.0
Length of gas path among boiler tubes with three-pass horizontal baffling—feet	45.0
Clear cross-section of gas passages of two-pass horizontally baffled boiler	
Over bridge-wall, square feet, ...	8.1
First pass, square feet	14.0
Second pass, square feet	8.4
Clear cross section of gas passages of three-pass horizontally baffled boiler	
Over bridge-wall, square feet	10.9
First pass, square feet	8.4
Second pass, square feet	5.6
Third pass, square feet	5.6

SUMMARY OF TEST DATA AND RESULTS.

The accompanying table gives the average of all data and the calculated results of the 19 tests. The calculations were made according to the rules given in the Code of Testing Steam Boilers of the American Society of Mechanical Engineers. The method of calculation is outlined in Bulletin 23 of the United States Bureau of Mines.

Method of Firing: On all the tests a modification of the spreading method of firing was used. When firing, the coal was thrown on the thin spots in the fuel-bed, omitting the high places. Coal was fired in small quantities at short intervals. By this method it was possible to keep the fuel-bed uniformly thick all over the

grate without the use of a rake or other fire tool. This method of firing was particularly successful with the Clinchfield coal. Most of the tests with the Clinchfield coal were run without using the rake at all during the day.

Behavior of the Coals on the Grate: The Pocahontas coal caked considerably. Perhaps a large part of this caking property was due to the fact that the coal contained a high percentage of slack. The freshly fired coal fused and formed a crust on the surface of the fuel-bed. This crust cracked in some places, and through the cracks air passed into the furnace. When firing, effort was made to put the coal into the cracks of the fuel-bed. By this method it was possible to keep the fuel-bed in good condition from one to three hours without using the rake. When the fuel-bed became too uneven, the crust was broken and the fuel was leveled with a rake. When the coal contained more lumps, there was less trouble from the formation of crust.

The Pocahontas coal did not clinker. At the end of a day's run the refuse pulled out of the furnace consisted of large pieces of free ashes. Smaller pieces of ashes were removed from the fuel-bed by rocking the grate two or three times a day.

The Clinchfield coal from the Dante mines was lumpy and burned freely. Usually, it was possible to run the fire through the day without using the rake. The coal caked very little but clinkered rather badly. The clinkers were no doubt partly responsible for the low capacity obtained on the first series of tests. When the fire was cleaned after the close of each test, the clinkers were pulled out of the furnace with difficulty. The clinker was formed in one large sheet over the entire grate and adhered to the side walls and the bridge wall. This clinkering property was the main objection the men connected with the operation of the plant had against the Clinchfield coal from Dante. The rocking of the grate gave no relief from clinker.

The coal from Crane's Nest looked much like the Dante coal and possessed all of its properties except that it did not clinker. In preparation it was not even as good as the Dante coal. There was a considerable quantity of impurities in the Crane's Nest coal, which raised the ash in it 2 or 3% higher than it was in the Dante coal, reducing the heat value by the same amount. However, the fact that the coal did not clinker made it a much better fuel for this particular plant than was the Dante coal. By shaking the grate three or four times a day the fuel-bed was kept in good condition. The rake was usually not used at all. After the close of the test when the fire was cleaned, practically no clinker was found on the grate. The refuse consisted of large pieces of loose ash and was removed easily.

It should be remembered that during the tests, the boiler was run considerably above its rated capacity all the time. During the regular operation, the boilers would not be run above their rated

capacity, and perhaps most of the time they would be operated below it. It is reasonable to expect that under those conditions, the efficiency will be even higher than is shown by the tests.

With the present standard baffling of the boilers, the greatest heat loss is in the chimney gases; that is, the loss of heat which is carried with the furnace gases and the excessive air supply from the boiler into the chimney. It is evident that all the air entering the furnace and setting, passes out into the chimney and carries along with it all the heat that it took to heat this air from atmospheric temperature to the temperature of the flue-gases, which is usually about 550 deg. F. During the last series of tests, the writer measured with an anemometer the velocity of air entering the ash-pits of the test boiler and also of boiler No. 1, which was equipped with the standard vertical baffles. It was found that on the test

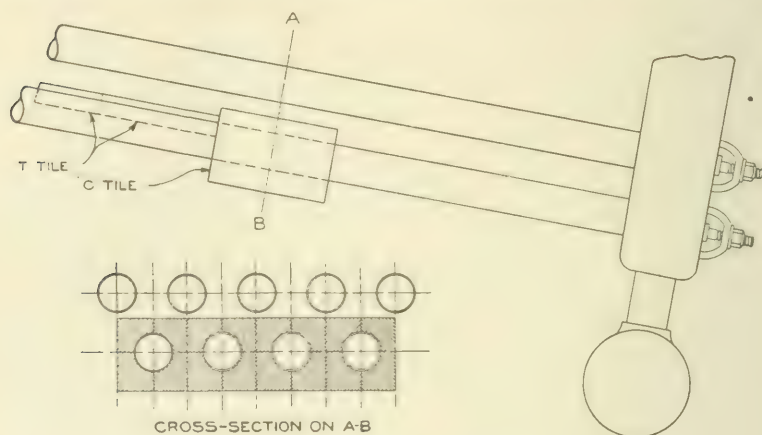


Fig. 8.—C Tile On Bottom Tubes.

boiler the velocity was about 450 ft. per minute; on the other boiler it was about 800 ft. per minute, or nearly twice as much as on the test boiler, although only about two-thirds as much coal was burned with the standard boiler as with the three-pass test boiler. This velocity measurement showed conclusively that entirely too much air was used in the standard boiler. It should be stated here that the area of the ash-pit doors on both ash-pits was the same.

In the preceding paragraph, the aim is to show that high draft over the fire is often misused to draw too much air into the furnace and is in that case detrimental to good efficiency. In the horizontal three-pass boiler, the draft over the fire is considerably reduced; there is less chance of drawing too much air into the furnace. Therefore, with careless firing the difference in efficiency

in favor of the three-pass horizontal baffle is much greater than with careful firing. In other words, the horizontally-baffled three-pass boiler is more nearly fool-proof against the careless fireman.

DETAILS OF TWO-PASS HORIZONTAL BAFFLES.

The location of the baffle tiles in a two-pass horizontally-baffled boiler is shown in Figs. 3 and 4. The lowest baffle consists of T-shaped fire-clay tiles laid on the lowest horizontal tubes. The baffle extends from the front header 15 ft. towards the rear, leaving a space of about 3 ft. as an entrance for the gases among the tubes. To prevent the tiles from slipping down the inclined tubes, C-shaped tiles are clamped on to the tubes at the end of the baffle.

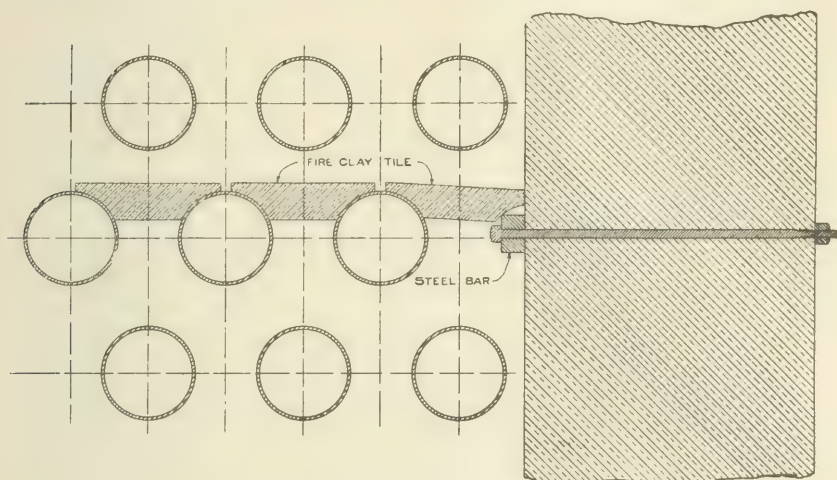


Fig. 9.—Details of Baffling.

Figure 8 shows the C-tiles in position. The T-tiles are 12 in. long, $1\frac{3}{4}$ in. thick, and about 6 in. wide on top. The price of these tiles is about 4c apiece at the yards at Mount Olive, Kentucky. There are 14 of these tiles laid between each two adjacent tubes. The C-shaped tiles are 12 in. long and cost about 12c each at the yards. Only one length of these tiles is placed on each tube at the end of the baffle.

The space between the tube and the wall at the left is closed as shown in Fig. 4. The soot is blown through the wall at the left, and therefore the arrangement of the tiles at the left interferes with the blowing of the soot above the lowest row of tubes.

The second or middle baffle is located on the sixth horizontal row of tubes from below. It consists of T-shaped fire-clay tiles same as those used on the lowest baffle. The small thickness permits

them to slip easily between the tubes when they are being put in place. They can be put in from the top with a specially designed pair of tongs. The baffle extends from the rear header 15 ft. towards the front. An opening of about 3 ft. is left between the baffle and the front header for the gases to enter from the lower pass into the upper one. The weight of the tiles and the inclination of the boiler tubes keep the tiles in place, and therefore there is no need of clamping them. The space between the tubes and the wall at the right can be stopped with half bricks, the bricks being split longitudinally. The space on the left may be closed in two ways. A steel rod 1 by 1 in. in cross section can be bolted to the wall about 1 in. below the top of the row of tubes supporting the middle baffle, so as to extend the full length of the latter. The same fire-clay tiles can be used then to close the space as shown in Fig. 9. Perhaps the easiest way of fastening

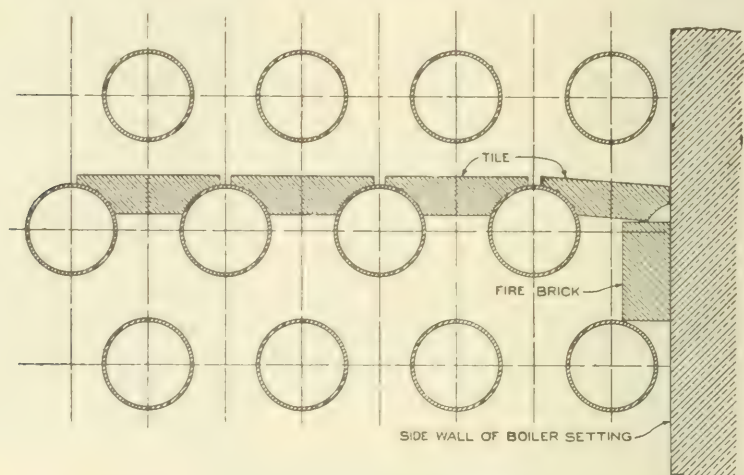


Fig. 10.—Details of Baffling.

the steel rod onto the wall and placing the tiles is by making two or three holes in the side wall and working through these openings. Another way to close the space is to place a row of bricks against the wall on the tube of the next lower horizontal row and to use this row of bricks to support the tiles as shown in Fig. 10. If this method is used, the opening for blowing the flues would have to be spanned with an iron bridge as shown in Fig. 11. The bridge is made of two pieces of $\frac{1}{4}$ by $1\frac{1}{2}$ in. flat iron riveted together. The construction is shown at the foot of Fig. 11.

The narrow space between the tube and the wall can be closed by common fire bricks split longitudinally.

The third baffle is laid on the top row of tubes and extends from the front header $15\frac{1}{2}$ ft. towards the rear, leaving a space 30 in. wide. The baffle is made of the same tiles as the other

baffles. To keep the tiles from slipping down the inclined tubes, the last 12 in. of the baffle consist of a row of cast-iron tiles clamped onto the tubes as shown in Fig. 12. The space between the tube and the wall on the left can be spanned, as shown in Fig. 10. The space at the right is closed with half brick pieces. The top of the bridge-wall in front is about 10 in. above the grate and about 10 in. below the first row of tubes, and slopes down towards the rear at the same angle as the tubes of the boiler.

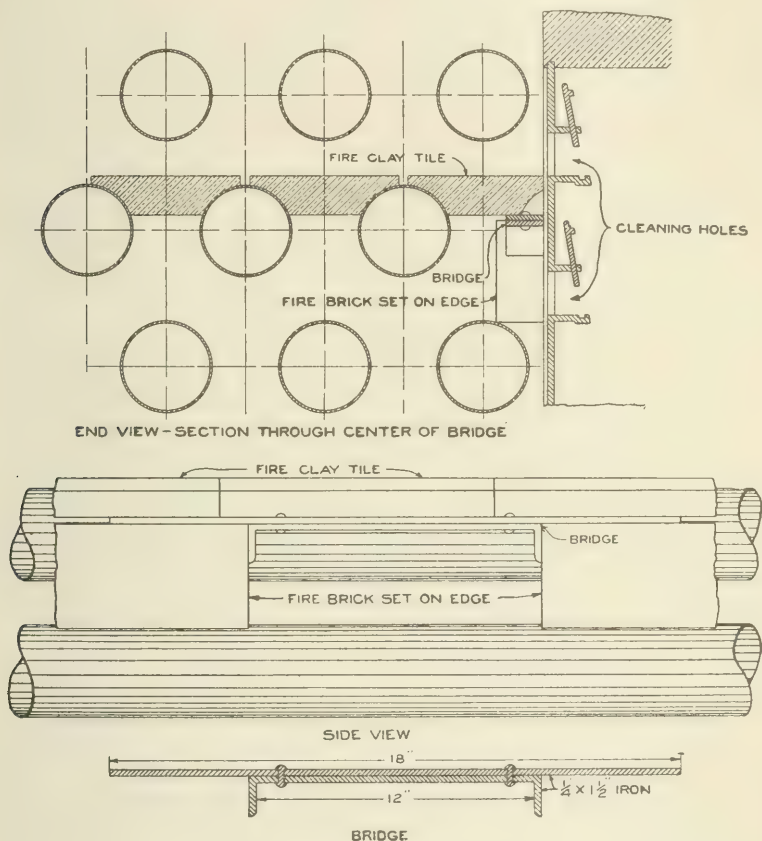


Fig. 11.—Details of Baffling.

The mud-drum is protected with a wall 13 in. thick and 2 or 3 in. higher than the top of the drum. Figures 3 and 5 show the protecting wall in position.

DETAILS OF THREE-PASS HORIZONTAL BAFFLES.

The location of the baffles on a three-pass boiler is shown in Figs. 5 and 6. The lowest baffle was placed on the second row

of tubes from the bottom because it is difficult to close the wide space between the tube and the wall at the left without interfering with the blowing of the flues, which is done from this side. The wide space between the tube and the wall at the right can be closed as shown in Fig. 6 or by the method shown in Fig. 10. The tiles used for this baffle are the same as those used for the baffles on the two-pass boiler. The baffle is tight against the front header and extends 15 ft. towards the rear, leaving the opening of 3 ft. between the end of the baffle and the rear header.

The second baffle is placed on the fifth horizontal row of tubes from below. It is made of fire-clay tiles, which are the same as

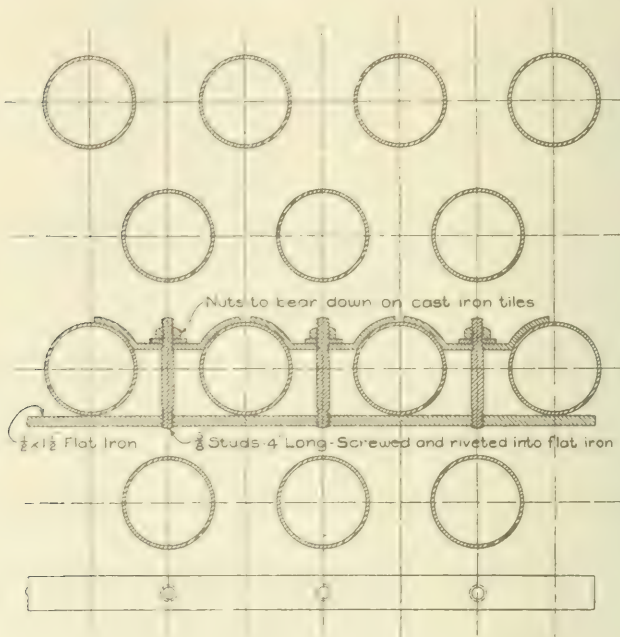


Fig. 12.—Special Baffling With C. I. Tile.

those used for the lowest baffle. The second baffle is tight against the rear header and extends 15 ft. to the front, leaving an opening of 3 ft. between the front header and the end of the baffle.

The third baffle rests on the seventh row of tubes from the bottom. It is tight against the front header and extends 15½ ft. towards the rear, leaving a space of 30 in. between the rear header

and the end of the baffle. The baffle is made of the same fire-clay tiles as the two lower baffles. To keep the tiles from slipping down, the last 12 in. of the baffle consist of cast-iron tiles clamped down to the tubes as shown in Fig. 12. The flat iron holding the studs is slipped, with the studs in horizontal position, between the third and fourth row of tubes, and then turned to bring the studs up. The cast-iron tiles have $\frac{3}{4}$ -in. holes in the center which fit over the studs. The tiles and the clamp are secured in position by tightening the nuts with a special long-handled wrench.

The top baffle rests against the rear header and extends $15\frac{1}{2}$ ft. towards the front. The space left between the baffle and the front header is 30 in. wide. The baffle is made of fire-clay tiles.

The spaces between the tubes and the wall at the right are closed by half bricks. The wide spaces at the left are closed by means of the steel rod supports as shown in Figs. 5 and 8. The wide spaces can be also closed by the method shown in Figs. 10 or 11. It may be found preferable to take the side walls down and rebuild them, closing the wide spaces with bricks. In case this is done, the lowest baffle could be placed on the lowest row of tubes. The bridge-wall is moved and the mud-drum protecting wall built in the same way as explained in connection with two-pass boiler.

APPROXIMATE COST OF MATERIAL FOR BAFFLING WITH TWO HORIZONTAL PASSES.

630—T-shape fire clay tiles, 12 in. long, $1\frac{3}{4}$ in. thick.....	\$25.00
40—C-shape fire clay tile, 12 in. long.....	4.80
15—Cast iron tiles, 12 in. long.....	2.25
Freight	25.00
	\$57.25

APPROXIMATE COST OF MATERIAL FOR BAFFLING WITH THREE HORIZONTAL PASSES.

840—T-shape fire clay tile.....	\$33.60
40—C-shape fire clay tile.....	4.80
15—Cast iron tiles.....	2.25
Freight	30.00
	\$70.65

All this material can be purchased from the Harbison-Walker Refractories Company, Pittsburgh, Pa.

The fire-brick from the partitions which are at present between the tubes and the steam drum can be used to reconstruct the bridge walls and build the protecting walls in front of the mud drum.

STANDARD ORIGINAL RAFFLING.

Test number	1	2	3	4	5	6	7
Kind of coal	Poca- hontas	Poca- hontas	Clinch- field	Clinch- field	Clinch- field	Poca- hontas	Poca- hontas
Date of test	Mar.5	Mar.6	Mar.18	Mar.21	Mar.21	Mar.21	Mar.22
Duration of test, hours	5.08	10.25	5.91	11.25	11.33	11.57	11.88
Steam pres. by gauge, lb.	140	140	140	140	143	145	145
Draft in breeching, in. of kerosene.	1.0	1.0	1.0	7/8	7/8	7/8	7/8
Draft in furnace, in. of kerosene.	3/4	7/16	7/16	7/16	7/16	7/8	7/8
Temp. of external air, Deg. F.	42	37	74	68	81	80	56
Temp. of fire-room, Deg. F.	54	52	80	75	88	85	71
Temp. of steam, Deg. F.	361	361	361	361	362	363	363
Temp. of feed-water, Deg. F.	79	73	78	79	84	90	86
Temp. of chimney gases, Deg. F.	584	610	519	547	615	618	606
Size and condition of coal	ROM	ROM	ROM	ROM	ROM	ROM	ROM
Coal over 4 in. screen, percent.	.....	.....	55	.....	.....	25	25
Coal through 1 in. screen, percent.	.....	75	.....	40	.....	50	.....
Weight of coal fired, lb.	5356	13508	6184	12385	13383	14404	12982
Total ash and refuse, lb.	458	710	118	738	987	1039	693
Percent. of clinker in refuse	.....	.....	.....	59	52	44	60
Coal consumed per hour, lb.	1054	1317	1047	1095	1181	1245	1092
Coal burned per sq. ft. of grate per hour, lb.	22.0	27.4	21.8	22.8	24.6	26.0	22.8
Total weight of water fed to boiler, lb.	44159	101238	48465	90468	98007	115739	104469
Factor of evaporation	1.187	1.193	1.189	1.188	1.183	1.177	1.181
Equiv. water fed to boiler, lb.	52414	120776	57624	107475	115942	136224	123378
Equiv. evap. per hr., lb.	10317	11783	9767	9553	10233	11774	10385
Horse power developed	299	341	283	276	297	341	301
Percentage of builders rated horse power developed	119	136	113	111	119	136	120
Water evap. under actual conditions per lb. of coal fired, lb.	8.25	7.48	7.83	7.34	7.32	8.03	8.05
Equiv. evap. per lb. of coal as fired, lb.	9.78	8.94	9.32	8.72	8.66	9.45	9.5
Average thickness of fuel bed, in.	8	8	6	6	6	8	7
Aver. percent. of CO ₂ in flue-gases	7.3	8.8	7.2	6.54	.....	7.7	8.89
Aver. percent. of O ₂ in flue-gases	.....	.....	.....	.....	11.2	10.63	12.5
Aver. percent. of CO in flue-gases	.....	.....	.....	.....	.45	.16	.15
Max. percent. of CO in flue-gases	.....	.....	.....	.....	2.2	.4	.6
Number of samples analyzed	.....	.....	.....	.....	23	26	25
Air used per lb. of carbon, lb.	.....	.....	.....	.....	30.3	27.6	32.6
AVERAGE COMPOSITION OF COALS.							B.t.u.
Pocahontas	.....	.....	Moisture	Ash	Vol.	Fixed Carbon	14828
Clinchfield	.....	.....	.62	4.9	17.12	77.36	14122
			.77	7.9	32.00	59.33	

HORIZONTAL TWO-PASS BAFFLES.

Test number	8	9	10	11	12	13	14
Kind of coal	Pocahontas	Pocahontas	Pocahontas	Clinchfield	Clinchfield	Clinchfield	Pocahontas
Date of test	May 7	May 8	May 9	May 14	May 15	May 16	May 17
Duration of test, hours	11.00	11.00	11.08	10.58	11.00	10.88	11.08
Steam pres. by gauge, lb.	145	145	146	146	146	146	146
Draft in breeching, in. of kerosene	11/16	11/16	11/16	3/4	13/16	13/16	13/16
Draft in furnace, in. of kerosene	5/16	5/16	5/16	5/16	5/16	5/16	5/16
Temp. of external air, Deg. F.	78	80	78	75	65	72	66
Temp. of fire-room, Deg. F.	85	92	92	85	75	82	76
Temp. of steam, Deg. F.	363	363	363	363	363	363	363
Temp. of feed-water, Deg. F.	95	98	98	90	90	92	87
Temp. of chimney gases, Deg. F.	485	522	541	588	543	533	550
Size and condition of coal	ROM	ROM	ROM	ROM	ROM	ROM	ROM
Coal over 4 in. screen, percent.	15	20	20	35	35	35	.....
Coal through 1 in. screen, percent.	60	55	50	30	25	30	.....
Weight of coal fired, lb.	11502	12000	12600	13500	14100	13950	13800
Total ash and refuse, lb.	539	744	820	1040	690	1114	873
Percent. of clinker in refuse	67	65	70	53	.....	57	55
Coal consumed per hour, lb.	1046	1090	1137	1276	1282	1281	1245
Coal burned per sq. ft. of grate per hour, lb.	21.8	22.7	23.7	26.6	26.7	26.7	26.0
Total weight of water fed to boiler, lb.	99885	104000	106373	108265	117817	113802	115504
Factor of evaporation	1.172	1.169	1.169	1.177	1.177	1.174	1.180
Equiv. water fed to boiler, lb.	117065	121576	124350	127427	138651	133603	136295
Equiv. evap. per hour, lb.	10462	11052	11222	12044	12606	12279	12300
Horse power developed	308	320	326	349	365	356	356
Percentage of builders rated horse power developed	123	128	130	139	149	142	142
Water evap. under actual conditions per lb. of coal as fired, lb.	8.68	8.67	8.44	8.02	8.35	8.16	8.37
Equiv. evap. per lb. of coal as fired, lb.	10.18	10.13	9.87	9.44	9.83	9.57	9.87
Aver. thickness of fires, in.	7	7	8	6	6	6	8
Aver. percent. of CO ₂ in flue-gases	7.2	7.5	8.2	7.76	9.5	9.3	10.8
Aver. percent. of O ₂ in flue-gases	11.5	11.7	11.26	.....	9.3	8.85	.....
Aver. percent. of CO in flue-gases	.16	.15	.2	.....	.....	.....	.....
Max. percent. of CO in flue-gases	.4	.6	.4	.....	.....	.....	.....
Number of samples analyzed	18	28	28	.....	19	16	19
Air used per lb. of carbon, lb.	33.5	32.4	29.5	.....	26.2	26.7	.....
AVERAGE COMPOSITION OF COALS.							
	Moisture			Ash	Vol.	Fixed Carbon	B.t.u.
Clinchfield	.98			9.85	29.00	60.14	13750
Pocahontas	1.12			5.5	15.76	77.62	14731

Test Number	Kind of coal	15 Clinch- field	16 Clinch- field	17 Clinch- field	18 Poca- hontas	19 Poca- hontas
Date of test						
Duration of test, hours						
Steam pres. by gauge, lb.						
Draft in breeching, in. of kerosene						
Draft in furnace, in. of kerosene						
Temp. of external air, Deg. F.						
Temp. of fire-room, Deg. F.						
Temp. of steam, Deg. F.						
Temp. of feed-water, Deg. F.						
Temp. of chimney gases, Deg. F.						
Temp. of condition of coal						
Size and condition of coal						
Coal over 4 in. screen, percent						
Coal through 1 in. screen, percent						
Weight of coal fired, lb.						
Total ash and refuse, lb.						
Percent. of clinker in refuse						
Coal consumed per hour, lb.						
Coal burned per sq. ft. of grate per hour, lb.						
Coal burned per sq. ft. of grate per hour, lb.						
Total weight of water fed to boiler, lb.						
Factor of evaporation						
Equiv. water fed to boiler, lb.						
Equiv. evap. per hour, lb.						
Horse power developed						
Percentage of builders rated horse power developed						
Water evap. under actual conditions per lb. of coal as fired, lb.						
Water evap. per lb. of coal as fired, lb.						
Equiv. evap. per lb. of coal as fired, lb.						
Average thickness of fires, in.						
Aver. percent. of CO ₂ in flue-gases						
Aver. percent. of O ₂ in flue-gases						
Aver. percent. of CO in flue-gases						
Aver. percent. of CO in flue-gases						
Max. percent. of CO in flue-gases						
Number of samples analyzed						
Weight of air used per lb. of carbon						
AVERAGE COMPOSITION OF COALS.						
	Moisture	Ash	Vol.	Fixed	Btu.	
Clinchfield						
Pocahontas						

DISCUSSION.

A. Bement, M. W. S. E. (Chairman): Some ten or twelve years ago I met Mr. Ray, and we worked together some time. Soon after meeting Mr. Ray, I met Mr. Kreisinger. I know what these gentlemen have been doing since then, and that the work in which they have been engaged is one of great importance. So I consider it not only a pleasure but an honor to preside at this meeting. The subject for discussion is one of very great industrial importance.

Mr. W. L. Abbott at one time said that coal-burning is a dirty proposition and for that reason we do not get very close to it. This no doubt is true, but it is a fact that coal-burning is an important matter; that the mining, transportation, and utilization of coal is a very complicated business, and on account of its complication it has not been very well understood. For this reason the matter has not received scientific treatment until recent years. It is, therefore, gratifying to observe in this case what intelligence and broad-minded commercial methods can accomplish. Such treatment is a marked contrast over what we see in every-day practice in the coal business.

It is only a few years ago that when a coal man heard about B. t. u.'s he was not only mystified, but the subject was a good deal of a joke to him. There are very few coal salesmen or operators who know much more about coal than its mining, how to put a price on it, and how to get it over the railroad.

In recent years, however, a new scheme has come into commercial operation, called service; in other words, giving the customer the result he wants rather than dumping some goods on him and leaving him to work out his own salvation. This requires intelligent work.

Messrs. Ray and Kreisinger began their work in Chicago (the home of modern coal-burning), with the Commonwealth Edison Co., under Mr. W. L. Abbott. They afterwards experimented at St. Louis, and finally went East and continued their work, for the Government, for a long time. Thus they have been very close to the coal problem and I think they have accomplished valuable results in a commercial way, because they know how to deliver service.

I would like to have it stated whether the coal used in these tests was of average quality.

Mr. Ray: I should say that the Pocahontas coal is a fair average of that used in the South. Perhaps much of it will run a little better. The question regarding the Clinchfield coal puts me in the somewhat embarrassing position of having to say that, owing to an internal misunderstanding in the Clinchfield companies, it happened that this particular coal was much below the guarantee. For instance, the regular contracts guarantee a minimum of 14,000 B. t. u., and there is a heavy rebate to the

customer for any coal that goes below that. In something like three years I suppose we have not been called upon to pay that rebate on over twenty cars. However, that has nothing to do with this paper, because when we figure the amount of heat in coal, and have sufficient draft to burn it, the amount of heat in a pound of coal makes little difference; the efficiency will figure out, roughly, the same. At one time when I was with the Government we found that as long as the coal did not clinker very badly we could almost say that all coals probably had an efficiency around 66% in that particular boiler.*

Mr. Bement: To open the discussion I will call on a man who is neither an engineer nor a coal man, but an editor who knows a great deal about the subject we have in hand tonight and much about that phase of the question mentioned in the introduction. We shall be glad to hear from Mr. Cushing, editor of *The Black Diamond*.

George H. Cushing (Editor of Black Diamond): This question, as Mr. Bement has properly said, means something more to the coal trade than anything yet presented. Until now the sale of coal has been governed by such consideration as the authors had in mind when they prepared Fig. 1. The distribution of coal has been fixed and predetermined by the freight rate charged the transit limit of any coal. Hence the zone in which it could be sold has been predetermined by some transportation official who being entirely outside the coal industry, had only a secondary and incidental interest in it.

It makes little difference whether the correction is made in the furnace only or whether the travel of gases is accomplished by making the boiler a part of the furnace. The mere matter of rearranging the coal-burning apparatus to suit the available fuel removes the railroad as the dominating influence. More to the point, it substitutes as the dominating influence, engineering, which, even granting its present imperfections, is far more an exact science than the rule-of-thumb now as ever governing the rate-making function.

As Mr. Bement said, I am not an engineer, I am not one of you. Even so, this question is one not to be considered solely from an engineering standpoint. Instead, it involves the engineer, the coal producer, the coal user and the manufacturer of coal-handling machinery. The last three are not engineers and, like myself, they talk about engineering without knowing much, if anything, concrete about the subject. It is difficult to get results with three parties to the equation uninformed or indifferent.

To arrive at the point I have in mind, I will discuss coal in

*I find there is no mention made in this paper of the work of Mr. N. W. Holliday, Jun. W. S. E., one of my assistants, and I wish here to pay tribute to his work on the tests and the drawings for this paper.

this way. Everything but the ash in the coal passes through the stack in the form of gas. The transformation of coal from a solid to a gas is not effected by manipulation but by a chemical reaction. To get any results by chemical reaction, the proportions, the temperatures, and all other conditions must be exact.

The question is: What are the chemical elements and proportions which influence combustion? The authors have told us in previous works that combustion is nothing but the uniting of particles of oxygen and carbon; the chemical reaction is the same whether the oxygen unites with fixed carbon or with the carbon in volatile matter. It has been my opinion that too much attention has been paid to the volatile matter and not enough thought has been given to the transformation of fixed carbon from a solid to a gas, but that is neither here nor there. The essential point is that to obtain results, the proportions and temperatures must be, within reason, exact.

This expands the issue when it is realized that no two coals are alike. To hear the salesmen talk, one would conclude that coal in one mine is different from the coal from another mine, working the same seam a thousand feet away. Sometimes the coal from different parts of the same mine shows a wide variation in analysis. This variability in coals in a narrow territory, and the greater variability in coals from different fields, makes it necessary to have a flexible furnace and boiler setting, if combustion is to be complete while using assorted fuels. This is especially true when the user may buy coals that range all the way from 15 to 36% in volatile matter, and which show equal fluctuations in other ingredients.

It stands to reason that under such conditions no one combustion set—whether it be a furnace alone or whether it be a boiler furnace—will prove adaptable without change, to burn all kinds and sizes of coal offered to it. On the contrary, the variability of coals requires a different setting or a different adjustment of any setting for each kind or size of coal that is to be burned.

Although I have heard hints that such conditions exist, I cannot see wherein there is any room or reason for conflict between the coal man, fuel engineer, and the manufacturer of coal-burning appliances, as to what should be done. It seems clear that all should unite to make such adjustments in the coal burning equipment as is necessary to get best results. The coal man and the furnace maker should be at one with the engineer.

Definite benefits to all arise from such harmony of action. Mr. Bement mentioned the question of service. The Standard Oil Company, you will remember, never made it a point to sell crude oil. Its profits and its interest came from and was in the refining process or the manufacturing process. The coal operator has been a generation behind in good merchandising by refusing to introduce the manufacturing process and in adher-

ing to his effort to sell the natural product. He is learning slowly that to make money he must make and sell a manufactured product, an exactly sized and carefully cleaned product. We have in Illinois and Indiana something like eighteen to twenty-two different sizes of coal. That is introducing the manufacturing process which is giving to the consumer precisely the size and kind of coal that he wants. Incidentally, that is advancing the price, the average price of the mine-run coal. Two-inch screenings, which formerly sold for 75 and 85c per ton, as a maximum, are now separated into five sizes of nut at an average price today of about \$1.15. That is profitable for the operator, but it can continue so only if the consumer learns to get the full benefit of that exact sizing. That depends entirely upon the furnace manufacturer. He must install equipment that will give the consumer the benefit of the carefully prepared coal. No furnace or boiler maker will do this for the coal man's benefit; the change must be profitable to him also.

It has been the practice of manufacturers to make a standard furnace and boiler setting. Theirs is a manufacturing business where cost of production is influenced by the patterns to be made. They favor—as an influence upon production cost—the sale of a standard set, made from patterns already on hand. So long as that theory holds, their business will consist of selling a certain amount of iron, fashioned into a certain fixed form. The time is here when their factory programs and selling arguments will be determined not by pattern-room costs but by consideration of how the buyers of their equipment can get power cheap. As a means to their own business ends, these manufacturers will realize the importance of the work of the authors. They will realize the importance to them of the work of the operator in sizing his coal. When their first consideration comes to be to produce a flexible boiler-furnace setting that will give the proper mixture of coal gas and air, while using any given coal, they may add to the selling price of their iron and brick the price of high-class engineering service. That puts an end to all consideration of a standard boiler, but it elevates the furnace and boiler manufacturer to the level of the engineer. This certainly is of distinct value to the manufacturer.

Thus, the tendency towards exact chemical reactions in the furnace or boiler-furnace is working a big change in the business of both the coal man and the maker of fire room equipment. Production costs and investments in both cases are greater, but the selling price of the product is higher. The latter more than offsets the former, hence it is a good business move.

However, the benefits are even greater to the man who buys and burns the coal. Today he does not have to buy a coal that he can use in a standard furnace of some make and pay the freight rate exacted by the railroad on that coal. He does not

even have to buy his coal by guess and trust to luck for results. He does not have to be content with 5 to 7½% of the efficiency from the coal he buys. On the contrary, he can, by selecting the size and kind of coal which comes to him at the fairest price and in more abundant supply, adjust his furnace to its use and cut his power bill, as I believe, squarely in two.

It is this complex and generally beneficial change that I have had in mind while watching the work of the authors for the last five or six years. I have believed and continue to think that they have done something for every phase of the fuel industry which the people most interested in that industry have been very slow to appreciate. I have felt that even the Government was slow to appreciate it. Lately many persons have begun to realize the great thing that has been done. The big men in the coal industry and the broad-minded manufacturers are beginning to realize the importance of these disclosures. For that reason I think, personally, that the presentation of this paper and its predecessors marks an epoch in the history of the coal industry.

These remarks are, perhaps, beside the point. Consideration might have been restricted to whether combustion should be confined to the furnace or be permitted to continue among the boiler tubes. It really seems unimportant where it takes place, so long as it does its work. At any rate, such matters have to do with manipulation of a furnace and boiler, and, as Mr. Bement told you, I am not an engineer.

Mr. Bement: The utilization of the volatile portion of coal seems to be the one great thing that we have been working at consciously and unconsciously for a number of years. If we consult old results of efficiencies we find that nearly all those figures were obtained with anthracite or semi-bituminous coal.

Before the use of the measure of efficiency, performance was stated in terms of evaporation per pound of so-called "combustible" (pure coal), but in practically every case a low volatile coal was used. When high volatile coal was employed in tests, a much lower evaporative result was obtained than could be had with the low volatile coal. From this the impression grew that it was impossible to get high efficiency with anything but a high quality of coal—in other words, anthracite or semi-bituminous coal.

If we figure a theoretical heat balance on those high and low volatile coals, we find that the possible efficiency is not so different—just a little higher for the low volatile coal, due to the difference in the moisture content. The reason for our not getting such comparative results in practice is that the volatile portion has not been completely burned, which is a furnace proposition. This is really what we have been working at. We have talked a great deal about boilers, but we have not been doing

so much with the boiler as we have with the furnace, and the results that have been obtained over the country generally in the way of improvement have been largely due to increasing the capacity of the furnace to burn the volatile portion of the coal.

In this connection, the proper view to take of the furnace in its relation to the character of coal it handles is that the better the furnace the better it will burn any kind of coal. If it is a furnace capable of burning a very poor coal, that is, a high volatile coal, it will also do well with a low volatile coal; no reference is made, however, to ash content, a matter of grate or stoker performance.

This matter of the loss of volatile matter in the form of smoke is a subject which we have dealt with in Chicago in various phases for a long time. There is a gentleman present who has had a great deal of experience in this line, and who has made a study of furnace performance in this city. I refer to the Chicago Smoke Inspector, Mr. Osborn Monnett. He has made a remarkable detailed analysis of furnace performance. I do not think he will attempt to prove my statement to you, but I assure you that sometime he may tell us about it. We would like to hear from Mr. Monnett.

Osborn Monnett, Assoc. W. S. E.: The setting shown in Fig. 2 is a very smoky proposition. It is the old standard B. & W. vertical-pass setting, hand fired, and probably nothing is more smoky than a setting of this kind. So that, in solving the smoke problem, we have been forced to horizontal baffles, and in forcing steam plant owners to horizontal baffles we have come in contact with violent opposition on the part of the engineer on the ground of loss of efficiency, expense of maintenance, expense of cleaning, the heating circulation, and so forth, and it is a source of a great deal of gratification to me to see tests quoted where horizontal passes have "made good" on efficiency. As a matter of fact, we are able to cite dozens and dozens of authentic cases of horizontally-baffled boilers where the efficiency equals the vertically-baffled boiler before the change was made, but the average engineer is very slow to make the change.

In Fig. 3, showing the two-pass boiler, we have a gas pass which approximates to a certain extent the so-called Sewall baffle, which is sometimes adopted on B. & W. boilers when they are horizontally baffled. The Sewall baffle imposes a greater draft loss through the boiler than the ordinary vertical pass. Our experience shows that if the draft at the stack side of the damper is assumed as 1, the draft over the fire will be 0.35. In other words, the draft loss through the Sewall baffle is 65%, whereas the draft loss through the vertical baffle is only 50%, so that, in a sense, the engineer has something on his side when he claims that there will be a loss either in efficiency or capacity. In making these changes, one of the things which we have to take into account in Chicago is the available draft.

I assume that these tests were not made with any reference to smoke consumption.

Mr. Ray: There are no smoke ordinances in our neighborhood.

Mr. Monnett: And I assume the smoke was fairly constant.

Did you take any readings or any note of the smoke performance on these things?

Mr. Kreisinger: No, no readings were taken on the smoke.

Mr. Monnett: When you were making the test on these horizontal baffles, you had an 80 ft. stack, I understand, and 1 in. of draft at the damper. I assume you had some sort of induced draft apparatus or steam ring.

Mr. Kreisinger: It was natural draft only, no steam jet.

Mr. Monnett: Not the 1 in. draft with an 80 ft. stack?

Mr. Kreisinger: Yes, sir. The breeching was only about 10 ft. long between the stack and the boiler.

Mr. Monnett: That was part of the test I did not understand. I do not exactly understand how you could get that draft with an 80 ft. stack. Theoretically it would take a 155 ft. stack to get that draft.

Mr. Ray: Where is that?

Mr. Monnett: Under the efficiency assumed in this test; for instance, we will say in the first test.

Mr. Ray: Those flue temperatures were high.

Mr. Monnett: With that flue temperature you ought to have about a 150 ft. stack to get that draft.

Mr. Bement: What was the diameter of the chimney?

Mr. Kreisinger: About 4 ft.

Mr. Monnett: Of course, I have not analyzed these tests or gone into them very extensively, but it occurred to me that the draft question was somewhat mysterious. I wanted it explained.

Mr. Kreisinger: It was a boiler set by itself and had an independent stack, of a large diameter.

Mr. Monnett: The draft question is so important in Chicago that it is the first point we note in a boiler test. We have to overcome all of the arguments of the operating engineer, and, in a great many instances, of the consulting engineer also, before we can get any kind of a change made in the setting, looking towards cleaning it up. We have standardized the gas passage with a Sewall baffle which will closely approximate Fig. 3, and find that without unduly cutting down the draft over the fire the first pass should have an opening of about 30% of the tube length; on an 18 ft. tube it would have 30% or 5.4 ft., or about 64 in. length for the first opening. The second pass we have

standardized as 33% of the tube length and the openings shown in the test are 36 in. for both. If the second opening is correct, the first opening would be rather small, because the temperature of the gas is, of course, higher at the first opening and consequently the volume is higher. We have found it is quite important to proportion these openings approximately according to the volume of the gas and the temperature of the gas, in order not to cut down the draft too much over the fire and cut down capacity, which comes right back to us; if we make any mistake it is up to us.

Those things are very interesting and I desired to call attention to them.

Mr. Bement: With reference to the matter of baffling, it may be well to call attention again to the fact that more or less confusion exists. Sometimes when a tile roof is in mind the term *baffling* is used. We should recognize this distinction and keep clearly in mind that the tile roof is the covering over the fire which is carried by the bottom row of tubes of the boiler (it serves the same purpose as an arch over the fire), while the baffling is strictly that portion of the apparatus which causes the gases to take a definite path over or through the heating surface.

Mr. Monnett has called attention to some of the difficulties that develop in the changing of boilers. The principal one arises from the fact that plants were not put in with the expectation of their being changed, and for this reason it is sometimes difficult to change them. In many instances height of boilers above the floor line or above what must be the grate surface, while considered satisfactory when the boilers were set in the old fashioned way, is hardly enough to admit of the application of a tile roof and to leave room enough over the top of the bridge wall. The gases leaving the fire in the furnace are of very high temperature and of very large volume; consequently they require considerable space through which they would flow if undue resistance is not set up. Therefore it is often the case that the plant would give better service if the boiler could be raised 6 in. or perhaps 1 ft., but it may not pay to do it.

The matter of horizontal baffling of Babcock & Wilcox or similar boilers is one which has presented difficulties, and has caused much controversy. Personally, I think the horizontal baffling is not as good as the vertical, and that the flow of gases across the boiler tubes of the Babcock & Wilcox type is preferable. I think the results obtained in the Government's work by the authors show that it is well to divide the gases up as much as possible, to change the direction of flow, to cause impingement with the heating surface to the greatest possible extent.

The Babcock & Wilcox boiler has a wide tube spacing.

Thus, the space between tubes being large, if gas flows horizontally it may do so in large mass, with the result that thorough contact does not take place. For this reason it is better for the gas to flow across the staggered tubes rather than parallel to them. With the Heine boiler the case is different, as it has a close tube spacing which divides the gas into small streams, and ensures thorough contact with the tube surface. Wherever possible, I have always caused the gases to flow across the tubes of the Babcock & Wilcox boiler, or, in other words, applied the tile roof and reversed the direction of flow of gas to the boiler, up at the back end with the exit in front. But there are many instances where it is necessary to use horizontal baffling; we should not be discouraged in any of those instances, but should keep in mind the fact that when we have new boilers to build we can then plan them according to improved methods.

T. A. Peebles (Green Engineering Co.): I would ask, regarding the baffling shown in Fig. 5, if any calculation was made of the ratio between the gas passages and the grate surface supplied. It seems to me, just from an inspection of this setting, that the gas passages, particularly in the last pass, are so small that a very large draft loss would exist. I fail to see how, with the draft afforded by an 80 ft. stack and a boiler baffled in that manner, it was possible to get sufficient draft over the fire to get a capacity, as shown here, of 303 h. p.

Also, I would ask regarding the repairing and cleaning of those baffles. It is true that in horizontal-pass boilers, unless some provision is made for proper cleaning of the tubes and repairing of the baffles in case the tubes are replaced, short-circuits will form where parts of the baffle are dropped out, or accumulations of soot will form, which will seriously obstruct the path of the gases. I have particularly in mind in this setting the space at the rear of the boiler where the gases travel from the third to the fourth pass through the tubes. (Fig. 5.)

Then, regarding the question of capacity with the same grate surface and draft, and the coals carrying as high as 30% of volatile as compared to Pocahontas, which has 20% of volatile, I would like to know something about the rates of combustion which were secured with the corresponding draft in the furnace. It seems that with the ratings and the B. t. u.'s of the coal as given, the capacities in the two cases would call for about the same rate of combustion per square foot with the same draft, and I would like to know if it was found on these tests that the Pocahontas coal containing 20% of volatile could be burned at the same rate of combustion under those conditions, that was secured with the Clinchfield coal.

Mr. Bement: Mr. Peebles asks in regard to the capacity obtained by the two boilers with three baffles, and also about cleaning the baffles. We made some experiments in Chicago

which are comparable with these tests. We baffled the boiler considerably—I should say the amount of baffling was about equivalent to the case in question—and we found the capacity to be increased with our baffling, so our greatest capacity was secured with the largest amount of baffling, and with the greatest reduction of draft to the fire, and the smallest amount of coal burned. We set up considerable resistance and yet did not drop our capacity.

In looking over this paper, I have wondered how far we could carry the baffling scheme without a drop in capacity. I am not aware of its ever having been carried far enough to give such a result. There is a point, of course, at which capacity would drop, but it is my observation that in cases such as those represented in the paper, it will not drop.

With reference to cleaning baffles or cleaning off a tile roof in a boiler like the Babcock & Wilcox type, it is a matter of some work. How much, I am not able to say, but when the advantages are considered it is not serious. There is a plant in Chicago operating eighty boilers with that kind of baffling and tile roof.

As I have said before, I think it is not a desirable thing in new work, but as a feature of change, in an attempt to improve existing conditions, it is sometimes a necessary expedient.

Charles W. Naylor, M. W. S. E.: This is a subject in which those working along the lines of steam engineering are much interested. One should thoroughly understand this paper before he undertakes to criticise it except in a general way, because these figures, in all probability, represent actual results—results of much painstaking labor; they have a certain definite value, more valuable to one person than another.

I should like to raise, or at least second, a good many objections voiced by the speakers. If I should make tests in my plant with Illinois and Indiana coals, they might be valuable as engineering data, but they would not be of any particular value to a man burning mine-run Youghiogheny or mine-run Pocahontas coals, which are entirely different from the coals we have here.

I agree with Mr. Monnett, that the results, as far as draft is concerned, cannot be obtained by that low stack.

There are a number of things which might have been mentioned, to advantage. For instance, the temperatures in the fire or over the fire. That is something which is studiously avoided, it seems to me. I have always considered that a power test ought to be made from the engineer's point of view as to efficiency as to the cost of evaporating water.

I am not competent to discuss this question, because I do not know what Pocahontas coal costs per ton. I do not know what Clinchfield coal costs per ton, neither do I know what

Clinchfield coal is. I have a sneaking idea of New River and Pocahontas coals, because we get them there.

I wonder if these gentlemen learned what it costs to evaporate water in this plant and if that had as much to do with the coal as the efficiency of the furnace, assuming that the efficiency of the furnace here induced the people to give preference to the Clinchfield over the other.

Mr. Bement: About twelve years ago, in Chicago, the Heine boiler was the means of introducing this question of baffling as an engineering fact. The experiments were conducted by a corporation using a number of that type of boiler. Mr. Fish, of the Heine Safety Boiler Co., is with us and we would like his opinion.

E. R. Fish (Heine Safety Boiler Co.): Since Mr. Bement has referred to the connection of the Heine boiler with the question of horizontal baffling, a brief resumé may be of interest.

The first Heine boiler in this country was built in 1882 by Col. E. D. Meier, recently President of the American Society of Mechanical Engineers, and to him is due the credit of having been the first to at least commercially promote the horizontal type of baffling. At that time the extended introduction of water tube boilers was just beginning and there was great opposition to this method of baffling boilers of this sort. The company persistently fought its way against powerful opposition, but the fact that its use has grown extensively and has been copied by many, is good evidence of the soundness of the method.

To a greater extent than ever before, the theory of combustion on which the adoption of the horizontal pass of gases was partially founded, seems to be in the way of being vindicated. Evidences throughout the country are to the effect that large combustion space is absolutely needed to burn our high volatile coals, whether they be the good coals from the East or the poorer coals from the Central West. These furnace conditions make the adoption of the horizontal baffling for the purpose of carrying the gases parallel with the tubes, the logical outcome, which, when combined with facilities for properly and effectively cleaning the external surfaces, makes a most efficient arrangement.

Because of the constant tendency towards the use of larger units and the restriction of the floor space available for the desired power, it has become necessary to put in far greater amounts of heating surface per unit of floor area, than has been the practice, previously. This has been made possible by reason of the development of several stokers which are so designed that a large grate area is provided for a narrow width, beside which the efficiency and rate of combustion is high.

This increase in height of the bank of tubes has introduced

the possibility of short-circuiting the gases by giving them opportunity to pass up diagonally among the tubes from the inlet to the outlet, thus rendering ineffective a portion of the absorbing surfaces. This contingency has been met by the introduction of the middle baffle, giving a double pass. Colonel Meier, I believe, was the first to suggest this, and a number of years ago he patented a shape and method of introducing tile for this purpose. Mr. Bement's experiments, however, were the first that had been made in a commercial way.

The particular tests which we are discussing, even though some of the criticisms regarding the data may be well founded, indicate very conclusively that the theory on which the horizontal baffling arrangement is based, is correct, for all these tests show harmonious results, which are at least comparable whether or not we consider them absolute.

It is, of course, absolutely necessary that efficient means be provided for preventing accumulation on the horizontal baffle, as well as keeping the heating surface of the boiler clean.

This is not the first time that the differences in the advantages of horizontal baffling have been demonstrated, for certain comparisons made as far back as 1898 show this and there have been a number of instances since.

The above remarks, of course, refer particularly to the approximately horizontal type of water tube boilers.

I do not agree with Mr. Bement's statement that a furnace that will handle a poor coal will also handle a good one. Coals vary greatly in their behavior when burning in a furnace, and in order to obtain best results it is necessary to adapt the one to the other. Indeed, some types of furnaces cannot handle some kinds of coal, and some forms of furnaces which burn some varieties of coal very efficiently are not at all adapted to other varieties.

Reference has been made to the comparison of results of boiler tests in terms of efficiency, and I cannot refrain from calling attention to the danger of attempting to compare these quantities except that they be regarded as only approximate. Most of the earlier heat determinations were made with crude and inaccurate forms of calorimeters which have been succeeded by more perfect forms of apparatus, so that because of this alone, the results are not comparable. The obtaining of a true sample of coal I regard as being practically impossible. There are several factors which enter into the problem, such as retaining the proper percentage of moisture; getting the proper portions of large and fine coal; the proper portions of foreign matter, etc.; the relative care of the parties selecting the samples and in preparing them.

I thoroughly believe that it is not far out of the way to say that the limits of error in heat determinations may be 5%

to 7% either way from the truth, and in consequence, determinations of efficiency must be regarded as only approximate.

For commercial purposes in buying and selling coal on a heat unit basis, the average would probably be about right, but the determination of a single small lot of coal is probably in error to the extent above mentioned.

As a concrete illustration, let me cite a case which came under my personal observation. We had a carload of coal with which to make a boiler test, the agreement being that the coal should not run less than 10,000 B. t. u. per ton. In order to determine whether to go ahead with the coal, the standard method of obtaining a sample used at this plant was followed.

A hollow pipe was driven successively into the coal at half a dozen different points, and the coal which was brought up each time in the pipe was used as a sample. On test this gave approximately 9,850 B. t. u. After the coal was unloaded, another sample was obtained by taking a shovelful from different points. The determination this time gave about 9,700 B. t. u. As these seem to indicate that the coal was below the agreed grade, and desiring to avoid having to wait for another carload of coal, it was then determined to take as true a sample as possible, and to this end, the whole pile was shoveled over, every sixth shovelful being put aside for a sample. After reducing the quantity in the usual way, the result this time gave approximately 10,050 B. t. u. This coal was then used to run the test and in order to be sure, it was again sampled in the same way as before, that is to say, by putting aside each sixth shovelful. The result this time gave approximately 10,480 B. t. u.

This reminds me of a little experience of the late Mr. W. H. Bryan, who made an experiment in the determination of the moisture of steam. He made three connections close together in the same pipe and used three calorimeters, all of which were the same. His observations gave three different results; so he said his conclusion was that the only way to be sure you are right is to use only one instrument. Possibly the only way to be sure we are right in making heat determinations of coal, is to make only one, but which is, of course, a scientific absurdity and leads me to remark, "a broad conclusion must not be drawn from a narrow premise."

Mr. Bement: Mr. Fish has told us some very interesting things and it is well for us to have before us this fact that he has mentioned with reference to the old efficiency figures. The original performance figures were derived from the evaporation per pound of "combustible," because at that time they did not have data from which efficiency could be derived. When engineers learned from the chemists that coal could be analyzed, they began to do it and then figured efficiency, which was further facilitated by the advent of the calorimeter.

One of the early calorimeters that was received with considerable confidence was that of Barrus. His instrument gave results much too low, which made his efficiencies high, and in nearly all of Barrus' tests it makes no difference what coal may have been used—the efficiencies are uniformly very high. We used to think this was due to the special skill of Mr. Barrus. Now we know it was due to the inability of his calorimeter to fully measure the heat value of the coal.

Later, Professor Carpenter brought out an instrument which we tested and found that it also gave low results.

It is only since we have been using the bomb calorimeter that we are getting good results.

In regard to sampling of coal, this depends a good deal upon the ability of the sampler, and that means a good deal more than some of us who have not been in the coal business, realize; but if we will take a fixed quantity off every wheelbarrow delivered for use at the furnace, a reliable result will be secured.

With further reference to baffling, it is often a fact that we have various ideas about boilers which are at times only preferences, not based on actual knowledge, but when we analyze some of the important features we obtain definite knowledge. Mr. Fish has mentioned the Heine boiler and we may consider it. The Heine (a horizontal tube boiler), as with all boilers, started small; in other words, it was a low boiler. As a small boiler it started as a very efficient boiler. With its small tubes and the small space between the tubes of the low boiler, the gas, instead of having a chance to go cornerwise through it, flowed along the tubes horizontally. It is a type of boiler much used today in Germany and gives good results. The Babcock & Wilcox boiler started as a low boiler; at first it was only seven tubes high, and as the gases flowed across the tubes there were but few tubes over which they could flow.

Thus the Heine boiler started as an efficient one and the Babcock & Wilcox started as an inefficient boiler. In response to the demand for larger boilers both manufacturers added more tubes, making the boilers higher. This resulted in relatively lengthening the path of gases with the Babcock & Wilcox type and shortening it with the Heine type. Therefore, as boilers increased in size the Babcock & Wilcox became more efficient and the Heine less efficient. This fact was illustrated by the tests in Chicago twelve years ago, when a Heine boiler seventeen tubes high had two baffles inserted, making it a triple instead of a single-pass boiler. Under these conditions it made 5% more horsepower with one-third less coal than it did as a single-pass boiler. The Heine Safety Boiler Co. are now building double-pass boilers as a regular article.

It is also a fact that the Heine boiler was the first one to afford anything in the way of the furnace as a feature of the boiler. It was not as high a type of furnace as we have now

when we cover the entire tube, but it was what we might call a water-top furnace.

There is another thing about the Heine boiler which Mr. Fish has not told us. It is regarding the circulation. The Heine boiler is what may be called a flat boiler, the tubes having comparatively slight slope. With the Babcock & Wilcox type the tubes are at a considerable angle, and one would expect the best circulation in it. The reverse is the fact, however, due not to the angle of the tubes, but to the greater water supply capacity of the Heine water leg, which feeds the tubes.

Mr. Ray: I notice that Mr. T. A. Marsh, of the Green Engineering Co., is here this evening. He knows a good deal about boilers and represents a boiler company very much entitled to be heard from. I hope he will offer some discussion.

T. A. Marsh (Green Engineering Co.): I want to express the appreciation which manufacturers of apparatus, furnace designers, and stoker designers have for a piece of concrete information of this sort.

We are, of course, familiar with the fact that large furnaces are required for properly burning coal, and I want to bear out what Mr. Fish has stated. However, I take exception to Mr. Cushing's statement that furnace design may perhaps some day become elevated to a problem of engineering. We now consider it an engineering problem of the very highest order to design furnaces for the various types of coal obtainable.

The furnace that is suitable for one coal, as Mr. Fish mentioned, will not produce results with another. A furnace that will burn Illinois coal at high rates of combustion would not burn Iowa coal having 30% of ash, or Texas coal having 40% of ash. The stoker manufacturer and furnace designer consider the coal first, and the furnace is designed to suit. For instance, we will design one style of furnace for installation in Des Moines, Iowa; something entirely different for Dallas, Texas, and something altogether different for Pittsburgh, all to serve the same type of boiler and for similar service, but with different kinds of coal.

Furnace design, therefore, having as variables, coal, boilers, ratings, draft, service, and local conditions, is a daily problem to us.

It is rather interesting to recall the history of furnace designing in Chicago. In 1908, with a setting similar to Fig. 2, a boiler was ordinarily set 7 ft. 6 in. from the header to the floor; and with proper draft, a sufficiently long arch, and furnace roof, a degree, at least, of smokelessness was obtained.

The next year 8 ft. of height was considered to be necessary, and later on 8 ft. 6 in. When some one mentioned a height of 9 ft. there was a sort of insurrection among the purchasers of boilers and installers of equipment. Today, if you should talk

to Mr. Monnett, the Smoke Inspector, about installing the type of boiler shown in Fig. 2 with less than 9 ft. 6 in. under the header, he would want you to show some very good reason for installing such a furnace.

As a matter of fact, one of the large firms in the East (consulting engineers and installing engineers of power plant equipment), has laid down the fixed rule that no Babcock & Wilcox type of boiler that they install shall be set with less than 12 ft. under the header and they are obtaining most excellent results. Furnaces so designed are vertical, while those with tile roofs are horizontal.

There are certain commercial disadvantages which I want to see mentioned in this discussion, because it is possible for those reading this paper, and lacking further information, to get the idea that it is a very simple matter to increase their efficiency, reduce their smoke, and obtain other pleasing results. Mr. Bement has referred to a plant of about 80 boilers with revised baffling which is being operated in Chicago without trouble from soot accumulation. The plant cited is unquestionably the Commonwealth Edison plant, where operation is far superior to that of the average manufacturing plant with two or three boilers. We have at times recommended this type of baffling (as shown in Figs. 3 and 5) for reasons similar to those discussed in the paper, and our customers have experienced difficulty due to soot accumulations. The boilers not being originally designed for such baffling, were not provided with proper soot-blowing holes.

There is another commercial proposition which we at one time met when we called Mr. Bement in as consulting engineer. In changing the type of baffling in the boiler, one is immediately confronted with the proposition that the hot furnace gases must pass a region which in the original design was constructed of common brick. A change in style of baffling as discussed must there be accompanied by a relining of the side walls of the combustion chamber with fire brick.

Didn't we puddle some side walls at Kankakee and have you in to consult?

Mr. Bement: I think you did. I was there as the expert for the Fuel Engineering Co.

Mr. Marsh: It happened two or three times, and I think it should be mentioned in case somebody else makes the same mistake, that the lining in the two-pass boiler in the combustion chamber should be No. 1 fire brick.

It would be interesting also to know the cost of this change, so any one can compare the cost of changing the baffling against changing the head room and getting height rather than length.

Mr. Bement: The matter of the effect of temperature in the brick-enclosed, or tile roof, furnace is an important matter.

It has led to a desire to obtain results equivalent to those of a tile roof by means of a very high setting. There are two sides to the question. The objection to the increased height is a question of first cost and maintenance. The objection to a lower setting and a tile roof is a question of maintenance. I think we will eventually come to a scheme whereby we will rob the furnace of a portion of its temperature, by means of auxiliary heating surface so located in the furnace that it will take off the sharp edge of the temperature. In this way we will reduce the cost of maintenance quite materially without retarding combustion or affecting efficiency.

As Mr. Marsh says, if one plans to reverse his boiler he must be sure to line the side walls with fire brick; if not, he will have trouble.

Chicago has been fortunate in having a great deal of expert information on the smoke question. No other part of the world, I think, has had more smoke inspectors who are college graduates and educated men. Some of them are in office and some have assumed more responsible work. One of the latter is Mr. Kuss. We shall be glad to hear from him.

R. H. Kuss: I cannot help thinking that our presiding officer betrays a feeling of relief, judging from the nature of his introduction, that there is at least one particular college graduate out of office when he emphasizes that point. Just why that should be so I am at loss to understand, inasmuch as I learned a great deal while in office, or, at least, thought I did, from Mr. Bement's own papers and discussions, and profited from their study to the best of my ability.

I am not ashamed to plead guilty to the charge of being one of those unfortunate apparatus men who have nothing to do but get orders, one of those fellows that tries to sell something whether his "prospect" wants it or not. But it is most surprising how hard some of us have to work in order to make an impression on the man who wishes to buy. It must be something besides our good looks that creates a favorable impression, so it must be the good looks of what we will guarantee to do. For the benefit of those who deride our methods let me say that when anybody can show us how to make our guarantees more attractive we shall be perfectly willing to abandon our much maligned standards.

Our company, the Edge Moor Iron Company, is not the only concern manufacturing boilers trying to do the best it can for its principals. As a matter of fact, no boiler concern that has been in the business of building water-tube boilers for any length of time, constructing a good, reliable article, has failed to take advantage of any concrete information available or has been behind the developments of the times.

Mr. Bement deserves a good deal of credit for guiding the

discussion so as to remain within the scope and meaning of the paper presented, so far as the rest of us permit him to do so. He has particularly emphasized the point that we must not confuse the furnace with the boiler or the treatment of the boiler. As stated by him, the tile roof furnace has its special advantages, and those advantages are separate and distinct from whatever a boiler may have by being baffled one way or another. As a concrete example of this idea, it is not obligatory to use a horizontal-pass baffle with a tile roof furnace. On the contrary, there are many more large boilers constructed with transverse baffling and tile roof furnaces, than with horizontal baffles. The aim is to obtain the furnace advantages of a tile roof while retaining the benefits of transverse boiler baffling.

This arrangement is sometimes successful and sometimes not. When failure occurs, it is usually not due to the failure to obtain a setting that is satisfactory because of a lack of either available capacity or efficiency, but because the combination imposes upon the operatives more onerous duties to maintain a reasonable degree of cleanliness on the gas side of the heating surface than obtains when the so-called standard settings are employed. It may be good engineering to seek the settings that afford the opportunity for highest efficiencies and capacities, but it is the height of engineering stupidity to design steam generating outfits that do not take into account their serviceability in the hands of operators who will prove incompetent or lax in the performance of the routine service imposed. There is a limit a designer may not exceed in the requirements he makes his followers live up to in such matters as cleaning soot from tubes, no matter how nicely a clean outfit of his design may operate. The practice of good engineering imposes recognition of the difference between test condition performance and daily operation performance. The authors certainly overlook this important angle of the situation if by their paper they wish to convey the impression that their boiler with three passes is to be preferred to the ones with a less number, even assuming that the slight advantage in efficiency indicated in the tests were due to the greater amount of baffling.

It has been my experience only today to have to answer for our company for the failure of the operators to keep soot from the top of a tile roof, and in that case every conceivable precaution was taken to provide facilities for cleaning. We become accustomed to guard against the shortcomings of operators, for the manufacturer cannot afford to overlook that important feature of how a boiler and its setting will be treated when once beyond his control. I have repeatedly said to prospective buyers, "We give you these definite performance guarantees and know that we can fulfill them, though high; we consider them valueless since they give you no clew as to how the

outfit will perform in the hand of your operatives. Compare these lower figures extending over thirty days with similar figures offered by our competitors." The difference can easily be as much as 15% where the settings are particularly difficult to keep clean.

While the attendance this evening is small, the authors may perhaps be somewhat comforted by the statement that other papers no less worthy have received less attention. I have in mind one such paper prepared for this Society by Mr. L. R. Stowe that I think was especially valuable. I dare say very few of those present have thought much about that paper, though many of us here tonight were present when it was presented. Mr. Stowe's paper, to my mind, gave a better and more advanced scheme of procedure touching on an analysis of boiler performance than anything advanced on the subject before or since. Yet that paper has not been fruitful of results in a general way.

I would ask the authors whether the illustrations are diagrammatic or accurate? I mean by that, were the illustrations prepared from drawings that were scaled or not?

Mr. Kreisinger: They are diagrammatic, not drawn to scale.

Mr. Kuss: That is unfortunate, because most of us think about and judge of these matters as they appeal to our sense of proportion. I notice, for instance, that the bridge wall height, while called 20 in. during this discussion, could not possibly be that in reality if the drawing is considered accurately drawn. I, for one, wish that the drawings were accurate as to dimensions, even if the dimensions were not supplied. Under the circumstances a discussion of the designs is not permitted except in a general way, for any detailed remarks might easily be based on misconceptions of the proportions actually used.

Mr. Kreisinger: Dimensions are given in a table under the heading "Principal Dimensions of Boiler and Furnace."

Mr. Kuss: Yes, length of tubes and so on. That is true. But the dimensions of the way the several parts are combined are not given either by figures or by scaled drawings. Now I do not wish to say that either the authors or the manufacturers are responsible for it, but Fig. 2 does not represent standard practice at all. If it does I confess absolute ignorance of the entire subject and abjectly apologize.

I would like to have seen curves of the important items worked out so that we might judge at a glance whether the advantages of one series appeared to be maintained for a given class.

For instance, I at once become suspicious of the tests (even knowing the authors as I do), thinking that the authors may have been mistaken in their interpretation of the results and their causes; that in seeking to confirm a preconceived idea they

have unconsciously deceived themselves into believing they have proven their views by attributing the apparent result to the wrong premise. In one paragraph of the paper we find this statement:

"In the preceding paragraph, the aim is to show that high draft over the fire is often misused to draw too much air into the furnace and is in that case detrimental to good efficiency."

Nobody can well gainsay that. Then:

"In the horizontal three-pass boiler, the draft over the fire is considerably reduced; there is less chance of drawing too much air into the furnace. Therefore, with careless firing the difference in efficiency in favor of the three-pass horizontal baffle is much greater than with careful firing. In other words, the horizontally-baffled three-pass boiler is more nearly fool-proof against the careless fireman."

This makes me suspicious to the extent, at least, of wondering whether the very pitfall assigned to the careless fireman may not have been in evidence while the authors were running the tests on the boiler with the smaller number of passes; whether the real causes for the lower combined efficiencies of the boiler and furnace were not due to the poorer furnace efficiencies alone, and that the number of passes following the furnace had nothing to do with the differences in the results. Confirmation of my view may be found in the item *thickness of fuel bed*, where 6 and 8 in. are mentioned. For the grade of coal supplied, such thicknesses are bound to give poor results to begin with.

As a matter of fact, the efficiencies are not good in any of the tests, not comparable with other tests just as carefully conducted, using identical or similar fuel, hand-fired, where standard furnace-boiler equipments were used. If changing the baffles failed to bring about efficiencies to equal or exceed like figures for standard arrangements, this paper may as well not have been prepared, unless it is intended to indicate what not to do in designing a boiler setting.

Surely, it is easy to meet the excess-air difficulty mentioned in the paragraph quoted above, if the remedy is simply to reduce the furnace draft without any regard to the effect. Closing the damper would do that effectually. It is my judgment that the remedy offered by the paper is calculated to do injury rather than good. The proper procedure is to increase the fuel-bed thickness, thus offering a higher fuel-bed resistance to air flow; the result is reduced air flow, though it is accompanied by an increase of furnace draft. Now it happens that for a given coal, of the semi-bituminous type in particular, hand-fired, there is a fuel-bed thickness or fuel-bed air resistance that affords best or good combustion results. This thickness or resistance may be fairly well defined for a particular available furnace draft; it

may happen that when the desirable fuel-bed condition is attained, the steam produced is either excessive or too little. The right move is to adjust the grate size so that the combustion rate is somewhere near right, using a fuel-bed thickness which will give good combustion results.

There are other very important items to be considered besides efficiency. One of the most important is elasticity or the ability to respond quickly to large load variations without excessive efficiency sacrifices. The authors tell us that the arrangement is more nearly fool-proof, that is, it is less elastic than the standard settings. I am of the opinion that the fool-proof idea is carried too far when a setting so inelastic as the one proposed, is offered.

The title of the paper is "The Adaptation of Boiler Furnaces to Available Coals." It is admitted that my discussion is getting away from the title, but in this particular I am not a greater sinner than the authors themselves, for, as Mr. Naylor has already pointed out, there are no data on the furnace proper to determine much about it, excepting gas values at the end of the gas travel which may not be representative of what occurred in the furnace. However, even a discussion of the boiler alone may be profitable.

I had hoped that I would somewhere find a reference to an idea that had been particularly brought forward by them years ago. I refer to the so-called Perry theory. While Mr. Perry never claimed originality for the equation expressing the idea, in fact, he specifically credits some one else with its development, the name of Perry identifies the subject sufficiently to illustrate what I have in mind in bringing up the matter. This theory has come to mean that after a condition has been reached where a boiler has delivered to it a certain critical amount of heat carrying medium a greater amount of the same medium at the same temperature may be delivered without a reduction in the percentage of heat absorbed. The thought is, a greater gas velocity can be employed with a corresponding increased capacity without detrimental efficiency reduction.

I have been skeptical as to the interpretation assigned to the equation so often previously quoted by the authors of this paper, and as the experimental work done by them gave them an opportunity to get some data on the subject, it is disappointing that no attempt was made either to verify their previous statements or to refute them. Contrary to the bald statement that an increase of gas velocity of itself insures a compensating, more rapid heat absorption, I have always felt that the equation representing the phenomenon of uniform efficiency of heat absorption presupposed the condition that the time of gas contact should still be equal to a condition where a lower velocity of gas travel was employed. To explain, the authors took the view that for a given boiler or heat absorber designed in a

definite way, to which varying quantities of heat-carrying medium at a given temperature are supplied in a given time-interval, thus bringing about higher or lower velocities of travel of the medium, depending upon whether the quantities are greater or less, there will be no difference in heat-absorbing efficiency over a wide range of quantities. My view is, the law as expressed by the equation really means that to be true, the absorber must be so changed in design that, while it may not increase in area exposed to heat, the velocity of medium travel is increased by the difference in design rather than by a difference in quantities of heat medium presented. In other words, it is feasible to consider a given boiler baffled with, say, three transverse baffles and an identical boiler with four transverse baffles. In this case, for a given quantity of gas, the velocity of the heat-carrying medium may be increased for the four passes and the time of contact with heat absorbing surface retained equal to the boiler with three passes. In such a case, the equation expresses a probability, but, as before stated, the presumption is that the time of contact must be constant though the velocity of gas travel is changed. The situation is similar to the expression, $pv = \text{constant}$, which is true for perfect gases only when the temperature remains constant.

It is true that the decrease of actual boiler efficiency for varying capacities remains fairly constant over a wide range of heat delivery. It by no means follows that the velocities of gas travel through boiler settings increase in proportion to the quantity of heated gases delivered to the boiler. As a matter of fact, the actual heating surface enveloped by heated moving gas is only a fraction of the total available heating surface supplied, and the fraction is increased or decreased according to whether the volume of gas is large or small. In other words, the larger gas volume employs more of the "dead space" of the boiler heating surface.

Mr. Kreisinger: I have one point to explain, and that is how the position of the baffle was determined. I think the figures in the table referred to, will show something about that. For instance, take the cross section of gas passages over the two-pass horizontal boiler; over the bridge wall it is 8.1 sq. ft. in area; the first pass is 14 sq. ft. and the second pass is 8.4 sq. ft. In the three-pass horizontally-baffled boiler it is 10.9, 8.4, 5.6, and 5.6 sq. ft. area respectively. When we wanted to have two passes, we moved the baffles from one row of tubes to another until we got the cross section of the passes approximately proportional to the absolute temperatures of the gases. Of course, it could not be made exactly; we could do it only approximately. In the boiler having the three-pass horizontal baffles you will see that it is quite a close approximation to the absolute temperature. In the two-pass boiler it is not so. The passage over the

bridge wall is somewhat small, due to the fact that the boiler was too near the grate. Probably we could have moved the lower baffle one row higher, as we did in the case of the three-pass. However, that was not the only reason why we moved it one row higher. It was so that the soot could be blown off from the top of the lowest baffle. Referring to Fig. 4, the boiler was blown from the left side. If we closed the space between the tube and the wall, as shown in the figure, we could not have blown the soot from that baffle. This was our experience in the second series of tests, and the next time we put the first baffle so that we could blow off the soot.

Somebody mentioned the fact that there are corners where soot accumulates. That is true, but it could be helped by making small doors in the side walls right at the space where the soot accumulates. The soot could then be pulled out with a hook or something of that sort. Of course, when we experimented with the boiler we did not want to tear down the side walls.

Mr. Ray: There are a couple of questions which have been asked that can be left for a written answer. Mr. Naylor asked about the cost of evaporating 1000 lb. of water. It happens all over the country that because of the prejudice against the high volatile coals they are uniformly sold on a lower basis of heat delivered for the money than the low volatile coals. That difference runs pretty high in percentage; I should say in the case of coals in southwestern Virginia, which are high volatile, against the coals from West Virginia, which are low volatile, a man would roughly get 10% more heat for his money out of the high volatile coals on the freight rates existing, so it is of advantage to alter the furnace to burn the high volatile coals. Very often a change of this sort can be paid for in the course of two or three months.

Mr. Kuss asked a number of questions, which can all be answered in written discussion. I think the main trouble between us and Mr. Kuss is that we are not all the time talking about the same thing.

The time element is in the Perry equation, and it is eliminated under certain circumstances only, much as though it is eliminated in the electrical generation of heat. We all know that the equation for the generation of heat by electricity does not contain the voltage factor. We say it is independent of voltage. As a matter of fact it is not. It cancels out from both sides of the equation, if you take the voltage on an electric light, for instance, and change to heat. Nevertheless, the voltage does not appear in the formula. In that same way the time drops out of Perry's equation. As a matter of fact, it is there.

E. A. Fessenden (Assoc. Prof. M. E., Univ. of Mo.): It has long been apparent that the most promising field for improving the efficiency of steam-power plants was in the boiler plant

rather than in the engines or turbines, and the obvious first step in this direction is to adapt the boiler furnace to the coal most available. The series of tests reported in this paper are a welcome addition to the rather meager literature upon this particular phase of the subject.

Many boiler manufacturers oppose changes in their standard methods of baffling and furnace construction, even though reliable tests have been published which show that this policy is unwarranted.

COAL	BAFFLING	TEST No.	DRAFT PRESSURES INCHES OF WATER			TEMPERATURES DEG. FAHR.			PERCENT CO ₂	PERCENT EXCESS AIR	LB. AIR PER LB. COMBUSTIBLE (ASSUMING CHEM. REQUIREMENT = 11.85)	LOSS TO STACK BTU. PER LB. COMBUSTIBLE	% LOSS TO STACK	BOILER EFFICIENCY (OVER ALL)	BOILER EFFICIENCY (1 = STACK LOSSES)
			IN BREECHING	IN FURNACE	LOSS THROUGH BOILER	CHIMNEY	FIRE ROOM	DIFFERENCE							
POCAHONTAS	ORIGINAL VERTICAL	1	1.00	.38	.62	584	54	530	73	151	27.6	3640	23.2	64.0	.833
		2	1.00	.44	.56	610	52	558	8.8	109	23.0	3220	29.5	58.5	.736
		6	.88	.38	.50	618	85	533	8.89	106	22.7	3030	19.3	61.9	.766
		7	.88	.38	.50	606	71	535	7.3	151	27.6	3670	23.4	62.2	.810
	Two Pass HORIZONTAL	8	.69	.31	.38	485	85	400	72	155	28.1	2790	17.8	65.9	.802
		9	.69	.31	.38	522	92	430	75	146	27.1	2890	18.4	65.6	.804
		10	.69	.31	.38	541	92	449	8.2	125	24.7	2770	17.7	63.3	.779
		14	.81	.31	.50	550	76	474	10.8	69	18.6	2230	14.2	63.3	.739
	Three Pass HORIZONTAL	18	.75	.19	.56	490	104	386	—	—	—	—	—	69.1	—
		19	.81	.19	.62	486	98	388	—	—	—	—	—	67.0	—
	ORIGINAL VERTICAL	3	1.00	.44	.56	519	80	439	72	155	28.1	3060	19.8	64.0	.798
		4	.88	.44	.44	547	75	472	6.54	178	30.6	3580	23.1	59.8	.778
		5	.88	.38	.50	615	88	527	7.7	140	26.4	3470	22.4	59.5	.767
															Means .781
CLINCHFIELD	Two Pass HORIZONTAL	11	.75	.31	.44	588	85	503	7.76	137	26.1	3270	21.1	66.3	.840
		12	.81	.31	.50	543	75	468	9.5	93	21.2	2490	16.1	69.1	.823
		13	.81	.31	.50	533	82	451	9.3	97	21.7	2460	15.9	67.3	.801
	Three Pass HORIZONTAL	15	—	—	—	507	94	413	9.0	104	22.5	2330	15.1	69.2	.815
		16	.75	.25	.50	501	98	403	9.2	100	22.0	2220	14.4	71.6	.837
		17	.81	.19	.62	503	105	398	—	—	—	—	—	70.1	—
															Means .816

The accompanying table has been prepared to bring out more clearly some points of comparison between the different methods of baffling employed in the tests.

The draft loss through the boiler passages is less for the horizontal two-pass baffling than for the original baffling. The number of complete reversals of the gas stream is the same for the two cases but two-pass horizontal baffling offers less re-

sistance between the points of reversal. The resistance of the horizontal three-pass baffling is slightly greater than the original baffling.

The chimney losses were computed by the following approximate method: From the ultimate analysis of many different kinds of bituminous coal the per cent of CO_2 by value was calculated, assuming complete combustion with different amounts of excess air and the results plotted as *per cent CO_2 against per cent excess air*. The curves for all the coals investigated were practically coincident. The column headed "per cent excess air" is made up of values taken from the curve using the per cent CO_2 given in the report. From this the amount of air per pound of combustible is computed. The chimney loss per pound of combustible is

$$(1 \text{ plus lbs. air per lb. combustible}) \times (\text{chimney temperature}) \times 0.24^*$$

The results indicate that the higher efficiencies shown by the horizontal baffling are due mainly to the decreased chimney losses. The overall efficiency of a boiler is

$$E = (1 - \text{chimney losses}) \times (1 - \text{all other losses}) \text{ from which}$$

$$(1 - \text{all other losses}) = \frac{E}{(1 - \text{chimney losses})}$$

The value of (1—all other losses) is given in the last column of the table. It will be noted that while these vary somewhat the averages for the different series are nearly constant, indicating that the chimney losses exercise the most important influence in the improved efficiencies.

It is to be regretted that sufficient data are not available to make complete heat balances for all of the tests. The approximate computations presented in the table may, however, be used in connection with the observed test data in comparing the performance with the different forms of baffling. The most striking features of the tests are the low draft loss and the low chimney losses with the two and three pass baffling. The lower chimney losses obtained in these tests with the three-pass baffling confirms the opinion expressed by the authors in other published papers that the rate of heat transmission increases with an increase of gas velocity.

It is to be hoped that the results of further investigations upon the effect of changes in the furnace construction and baffling of boilers with many kinds of fuel will be presented to the engineering public.

C. E. Augustine, Bureau of Mines: In 1909, experiments

*Specific heat of flue gases=0.24 (approx.).

similar to those described in this paper were made at the plant of the Westinghouse Electric Co. A boiler of the B. & W. type, with the standard three-pass vertical baffling, was first tested. It was then rebaffled with the Sewall baffling and again tested. The Sewall baffle is somewhat similar to the two-pass horizontal baffling shown in Fig. 3.

Four trials were made altogether under the conditions of operation as maintained for usual plant load. Complete records of results are not at hand, but I believe there was about 4% increased evaporation per pound of coal.

This boiler was equipped with a superheater, and where the original boiler gave a superheat of 100 deg. F. the change resulted in a drop of nearly 50 deg. F. After some months the engineer in charge of the plant decided to change back to the original baffling. Later, in order to give greater combustion space for gases before striking the tubes, the furnace was moved forward 4 ft., and the furnace arch lengthened to suit, but the standard vertical baffle was retained.

These boilers were built with the bank of tubes unusually high, about 18 horizontal rows, so conditions were somewhat different from those the authors of this paper had, and may account for the horizontal baffle not being an improvement in this instance.

W. M. Duncan (Illinois Stoker Co.): We have recently installed in Illinois under eight B. & W. boilers, Illinois chain grate stokers 12x12, giving 144 sq. ft. of active grate surface. These boilers are mounted with the lower portion of the boiler over the grates and are set 14 ft. from the lowest point of the boiler to the top of the floor line. The lower row of tubes is baffled horizontally for a distance of 14 ft. with a combination vertical baffle such as we assume they are using in the rebaffling of the B. & W. boiler. We have raised our bridge wall to within 3 ft. of the lower row of tubes and have built obliquely from the end of the grate approaching the tubes. We have installed our new type ignition arch on this installation and with these 600 h. p. boilers have obtained ratings approaching 2100 h. p. per boiler. We have found that the boilers will not stand up to this high rating, but in several instances have operated them for a period of four to five hours.

Over the former type of grates used under the same boilers we raised the evaporation from 5.68 lb. of water per pound of coal to 8.25 lb. of water per pound of coal.

This installation is connected with Green economizers, and in combination with these economizers we are obtaining a combined efficiency of 82%. The most economical operating point with a grate and boiler of the size mentioned has been determined at 1400 h. p. At this rating we are obtaining in gases 14%

CO₂, less than 0.1 of 1% CO and the remainder excess air. We have found this analysis of gas to be the most economical in operation.

When operating at the high ratings with a 6½ in. bed of coal we were using ¾ in. draft over the fire.

The grates are being driven at a very high rate and the new type of ignition arch setting being used, there was no difficulty whatever in maintaining ignition. The fuel being used is Illinois coal, running between 10,000 and 11,000 B. t. u. and running in screenings from 1¼ in. down to dust. The efficiencies obtained were not based on a ten-hour test, but on an average run of 30 days. The method of determining the amount of coal used was as follows: On the first day of each month the average cubical contents of the bunkers is determined and at the end of the month the same determination is made, an account being taken of the amount of fuel discharged into the bunkers per day during the intervening period.

The volume of water is determined by Venturi meters, and to get an accurate determination, two meters are used, one checking against the other. Induced draft is used in this installation, which accounts for the high ratings and the high possibility of draft ranges. We find, with the extremely large combustion chambers, that the deterioration of the brick work was nominal and not excessive to ordinary operation. We also find that with our new ignition arch over the old design we are able to get much higher ratings and also drive the grates at any speed desired without the difficulty of losing the ignition at the front end.

R. H. Danforth (Instructor, Post-Graduate Dept. U. S. Naval Academy): I have examined with great interest the paper by Messrs. Kreisinger and Ray, the more so as some of their conclusions agree in a very interesting manner with some data I have myself obtained in quite a different line, *i. e.*, the testing of boilers with oil fuel. In the paper is a comment on the action of high volatile fuels, to the effect that in a given boiler with a fixed grate surface the increase in output, other conditions being similar, is approximately proportional to the volatile matter burned.

With oil fuel we have in effect a condition where all the fuel is burned in the combustion space in a volatile form. This should mean that within reasonable limits, a given boiler should be able to produce almost any horse power desired, with approximately uniform efficiency. I have recently received data of two tests on a small tube, express type, marine boiler, burning oil of about 19,200 B. t. u. per pound. This boiler was run first under a low rating, and then under a rating as high as could be obtained, with the following results, which practically prove the above thesis:

	Low Rating	Maximum Rating
Pounds water evaporated per lb. oil.	13.86	12.47
Equivalent evaporation f. & a. 212 deg. F. . .	14.69	13.10
Boiler horse power developed.	382	1727
B. t. u. per lb. of oil.	19,300	19,300
Approximate efficiency of boiler and furnace	73.8	66.00

CLOSURE.

Mr. Kreisinger: Mr. Monnett called attention to the fact that the intensity of the draft given in the table is too high for the temperature of flue gases and the height of the stack. The draft was measured with a U tube filled with kerosene having a specific gravity of about 0.78. On the original log the drafts were recorded in inches of kerosene. On comparison of the table with the original log I find that the averages given in the table were not reduced to inches of water. Therefore, to obtain the draft in inches of water, the figures given in the table must be multiplied by 0.78. The height of the stack was not measured, but it appeared to be about 80 ft. The figure in the paper was furnished by the manager of the plant. Inasmuch as the same boiler and the same stack were used for all the tests, it was not considered important to have the exact height of the stack determined.

As to the size of the gas passages between the end of the baffles and the headers, they could well have been somewhat larger, but I do not see why they should be in proportion to the length of the tubes. It seems that they should be proportional to the cross section area of the passes, and these vary with the height of the boiler. A high boiler, when baffled horizontally, has larger gas passages than a low boiler.

The following table gives the intensity of draft at seven different places of the two-pass horizontally-baffled boiler. Each reading is the average of four readings:

DRAFT IN INCHES OF KEROSENE.

Breeching	Rear of 2d Pass	Front of 2d Pass	Front of 1st Pass	Rear of 1st Pass	Comb. Chamber	Furnace
0.85	0.70	0.55	0.47	0.47	0.35	0.32

All four measurements showed the same draft in the front and rear ends of the first pass. This is perhaps due to the fact that the resistance to the flow of gases into the first pass and out of it, is too high compared to the resistance of the pass itself, so that the drop of the draft through the pass was too small to be detected with an ordinary U tube. Furthermore, the front end of the pass is about 4 ft. higher than the rear end, which fact makes the measurements at the two places uncomparable. Strictly

speaking, draft measurements made in the ordinary draft gauges are comparable only when made at the same elevation. The greater the difference in the elevation of the two draft measurements, the greater is the apparent discrepancy in the reading obtained. Thus in the old Cahall vertical boiler it may be found by actual measurements that the draft in the furnace is 0.3, and 30 ft. higher in the breeching only 0.2 of an inch of water. According to the law that gases flow only from a place of high to a place of low pressure, the gases should flow from the breeching into the furnace. However, if account is taken of the difference in elevation of the two measurements it is found that, after all, the gases flow in the right direction.

I think Mr. Bement answered Mr. Peebles' question as to the high capacity developed by the three-pass horizontally-baffled boiler. I will add that when the resistance of the fuel bed to the flow of gases remains the same, the rate of combustion is not proportional directly to the draft over the fire but to the square root of the draft. It is stated in the paper that the carload of Clinchfield coal used on the first series of tests which were made with the standard vertical baffle, clinkered more than the two carloads used on the other two series of tests. Therefore, the high draft over the fire of the first series was partly due to high resistance of the fuel bed, which resistance also reduced the supply of air to the fuel bed and consequently the rate of combustion. For these two reasons the rates of combustion on the first and third series of tests may apparently be out of proportion to the draft.

As to cleaning the soot which accumulates on the horizontal baffles, especially the ones which are tight against the rear header, there is some cause for complaint. However, I believe that with a little perseverance that problem can be solved. I have already suggested a small cleaning door built into the side wall. Recently I have applied, with considerable success, the principle of vacuum cleaner to remove such accumulations of soot from a two-pass Heine boiler, and that seems to be a much better method than anything I have so far heard of. The vacuum is produced with an ordinary steam ejector, which, with a pressure of 125 lb., gives a vacuum of 16 to 19 in. of mercury. The suction from this apparatus is so great that it draws the soot out at the rate of a bucketful per minute. The ejector is shown in Fig. 13. The flexible hose connecting the suction nozzle to the ejector can be a piece of water hose 20 or 30 ft. long. It should be stiff enough not to collapse with the suction. For use in a B. & W. boiler, the suction nozzle can be a piece of $\frac{3}{4}$ in. pipe of suitable length, bent into such shape that any corner within the setting can be reached with it. If used with a Heine boiler, a $\frac{5}{8}$ in. copper tubing is better because it can be introduced into the boiler through the stay-bolt holes. The dis-

charge line should have no elbows in it. The first two pieces of the discharge line should be of about the dimensions shown in Fig. 13. Beyond these two pieces, old 4 in. boiler tubes can be used. The latter can be set together loosely, their only object being to take the dirt and steam out of the way.

Mr. Marsh asked about the cost of baffling the boiler horizontally. The cost of material is given at the end of the paper. The labor cost would be \$25.00 to \$40.00. The most difficult part in placing the baffles is to close the space between the tubes and the wall. Considerable space in the paper has been devoted to the description of a few methods of closing this space. When

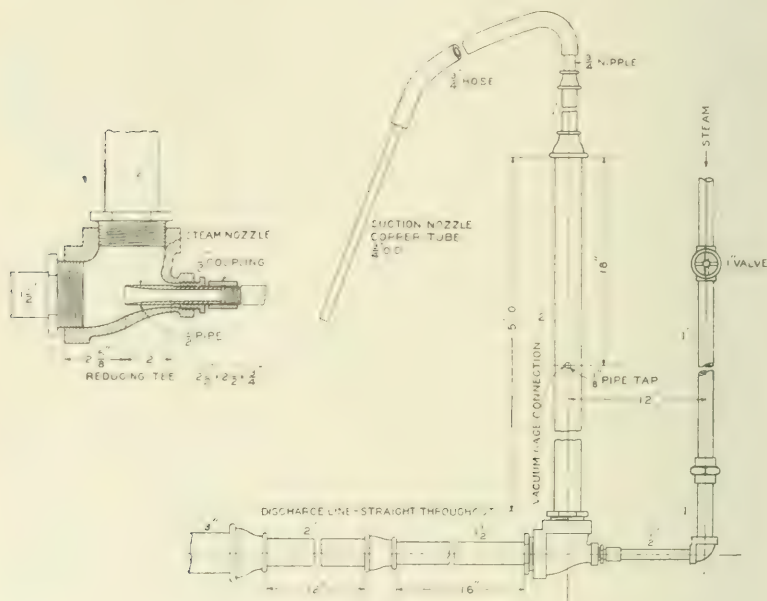


Fig. 13—Ejector.

installing a new boiler, this can be done by running the brick in the side walls close to the tubes.

Mr. Kuss's criticism in connection with the paragraph he quoted, perhaps arises because its connection with the tests is not made clear in the paper. The following explanation will clarify the statements made in the paragraph quoted:

Beginning with "Specific Description of Tests," the paper is taken bodily out of a report on the tests, which report was prepared for the General Manager of the Clinchfield Fuel Company. Some of the statements apply to boiler furnaces and boilers in general; others apply only to the case in question. The

statements in the paragraph quoted apply only to the specific case.

The boiler plant where the tests were made contained three boilers of the B. & W. type, each rated at 250 h. p. capacity. When fired with reasonable care each boiler could develop 300 to 350 boiler h. p. as shown by the tests. About eight months out of a year the load on the boilers is 400 to 450 h. p.; the remaining four months the average load is about 600 h. p., so that two boilers furnish all the steam ever needed. During eight months the two boilers operate under a rather light load. Each boiler has an independent damper, but all the dampers are out of reach of the fireman and cannot be adjusted to any desirable draft without a great deal of trouble. My observation was that the fireman never used the dampers. He fired about 10 shovelfuls at a time, piling the coal on the front part of the grate. The rear part of the grate was left uncovered. The fireman held the steam down by admitting a great excess of air into the setting through the uncovered portion of the grate. If this was not sufficient, and the safety valve blew off, the fireman opened the furnace door and closed the ash-pit. When the pressure went down he took a rake and pushed the heap of burning coal from the front part of the grate onto the rear portion, and put a new supply of coal on the front part. While the rear part of the grate was covered, the steam went up. It was easy for the fireman to get 400 to 450 h. p. out of the two boilers which were capable of developing 650 to 700 h. p. With this method of firing, the evaporation was about 6 lb. of water per pound of Pocahontas coal. This was determined by metering the water and weighing the coal daily for about three weeks. The average air supply under the regular operating conditions was perhaps 500% in excess. With a less draft over the fire the excess of air would be smaller. It is these conditions that the paragraph quoted by Mr. Kuss refers to.

The two-pass horizontally-baffled boiler was in regular service over two months, during which time the owners of the plants observed a considerable reduction in the coal consumption.

As to the tests, all three series were run with the same conditions, and the flue gas analysis shows approximately the same composition of gases. The regular plant fireman fired all of the tests, but he was supervised by one of the writers of this paper. He had to fire a little at a time and often, and kept his fire level.

Mr. Kuss did not say whether he considered the 6 in. to 8 in. fire thin or thick. The authors are well familiar with the Clinchfield and Pocahontas coal and they thought the 6 in. to 8 in. fire best suited for both coals, and for the condition under which the tests were run.

It may be asked why such a wasteful method of firing coal

was used under the regular operating conditions of the plant. The answer is that in that section of country firemen are paid \$1.20 to \$1.50 for 12 hours shift. Consequently, only indifferent men are attracted to the job, and in many plants they change frequently.

At different times I spent a few days in a plant showing the fireman how to burn coal economically, and usually succeeded in setting him in the right track. However, when coming to the same plant two months later I found a different man firing the boilers, using his own wasteful methods. It is nearly true what somebody has said, that anybody who would undertake the training of a plant fireman in the economical methods of burning coal, would have a problem of educating practically the entire negro population of the old South.

Therefore, any device which tends to save coal independent of the effort on the part of the fireman is particularly desirable in that section of the country. To be fair to all I must say that I have come across a few good firemen who know how to burn coal economically.

During the last three years the Clinchfield Fuel Company has done a considerable amount of mission work in the way of introducing economical methods of burning coal, among the cotton mills of the South. That the owners of the mills appreciate this work is best shown by the fact that the Cotton Mill Association of South Carolina are contemplating establishing their own central bureau for the purpose of introducing economic methods of generating power in their mills, and doing all kinds of allied testing work.

Mr. Kuss states that higher efficiency was obtained with boilers having the standard vertical passes. That is entirely possible. However, such boilers may have been higher and very likely had large furnaces. Mr. Marsh states that in up-to-date setting of a boiler with vertical passes the boiler is set as high as 12 ft. under the front header; thus a large furnace is obtained where good combustion can be secured. Not long ago I had an opportunity to examine the plans of some of the recent installations put in by the Green Engineering Company. In none of them was the boiler set less than 9 ft. under the front headers. When we compare these heights with the 5 ft. height (from floor to front header) of the boiler described in this paper, it is hardly necessary to explain further why an attempt was made to increase the combustion space of the furnace. If it were possible to enlarge the furnace and maintain the vertical passes without tearing down the setting, it would have been done. The horizontal baffling seemed the best possible solution to the problem. Originally it was contemplated to two-pass the boiler only, but after the tests on the two-pass boiler showed a marked improvement it was thought advisable to test the boiler with three horizontal passes.

The horizontal baffle is a specific rather than a general remedy. Aside from furnace consideration, high boilers are better heat absorbers when baffled vertically; low boilers are better heat absorbers when baffled horizontally. The reason for this is the fact that the length of the path of gases through the high boiler baffled vertically is greater than when baffled horizontally with two passes. The path of gases is longer in a low boiler when two-passed horizontally than it is when three-passed vertically.

Perhaps these statements can be made clearer by referring

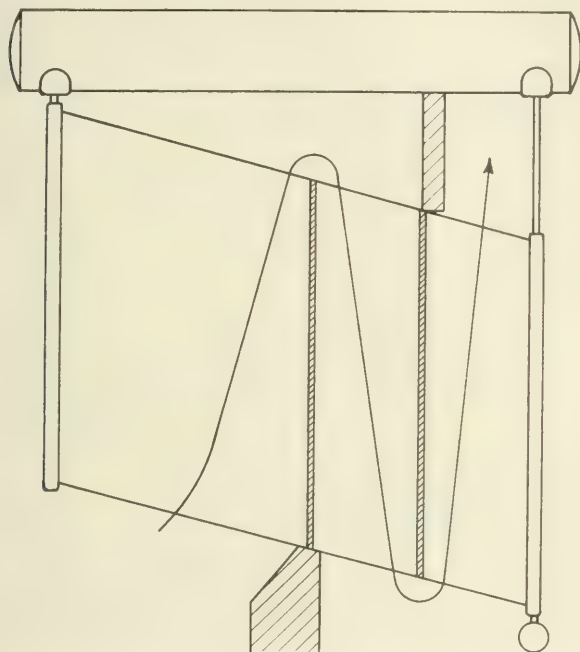


Fig. 14—High Water Tube Boiler Baffled Vertically With Three Passes.

to Figs. 14 to 17. In Fig. 14 is a high water tube boiler baffled vertically with three passes. The same boiler is shown in Fig. 15, two-passed horizontally. It is apparent that the path of gases in Fig. 14 is longer than in Fig. 15. In Fig. 16 a low boiler is three-passed vertically. The same boiler is shown in Fig. 17 two-passed horizontally. On account of the stirring of the gases, it would seem that a foot of length of the vertical pass is worth more than the foot of length of a horizontal pass.

From the preceding consideration, it is apparent why the so-called double decked B. & W. boilers give better results with

vertical baffling than when two-passed horizontally, providing that the furnace with the vertical baffles has a reasonable amount of combustion space.

There is another feature to be considered before attempting to re-baffle a boiler of the B. & W. type horizontally, and that is the superheating of the steam when the boiler is equipped with the superheater. It is evident that with the horizontally two-passed boiler the gases are not hot enough when they reach the superheater. Mr. Augustine reports that the low degree of superheat was the principal cause of failure of the horizontal

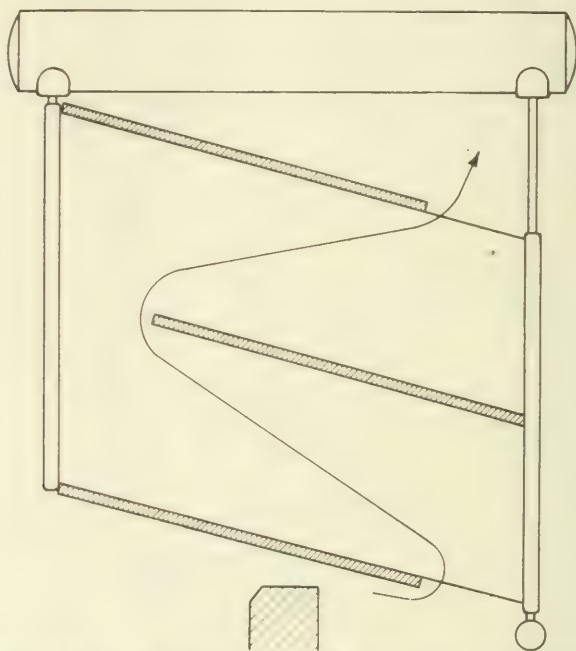


Fig. 15—High Water Tube Boiler Baffled Horizontally With Two Passes.

(Sewall) baffle tried at the plant of the Westinghouse Electric Company.

In the consideration of available coals, besides the high quality and low price there is another even more important factor, and that is the service. It is of little value to contract for a high quality of coal at a low price if the coal cannot be delivered when it is needed. A coal contract is closed between the coal company and the consumer; the coal is bought for a contracted price at the mines. The carrier—the railroad—never enters into the contract. If for any reason the railroad cannot

give regular service, the consumer suffers, although through no fault of the coal company.

During the fall and winter months there is usually shortage of coal cars, more on some railroads than on others, so that some coal districts suffer more than others. The Northeast and Northwest, where the demand for coal is higher in winter than it is in the South, are supplied with Pocahontas and New River coals. Also, the distances traveled by the coal cars in the Northeast and Northwest are long, so that the cars stay on the route a long time. For these and various other reasons the Pocahontas and New River regions seem to suffer more from car shortage than the coal fields farther south. As a result of this car shortage the users of Pocahontas and New River coals in North Carolina, and even in southeast portions of Virginia, may have to draw their coal supply from the Virginia and Tennessee coal

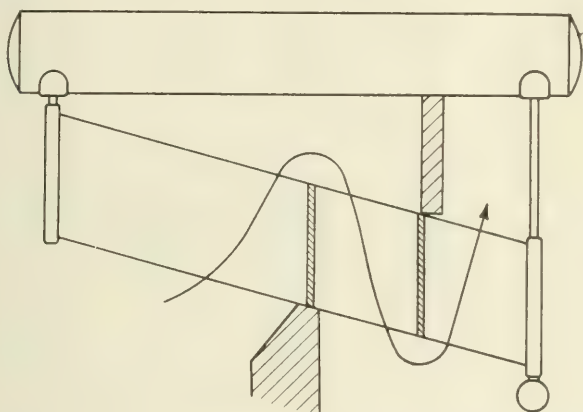


Fig. 16—Low Boiler Baffled Vertically With Three Passes.

fields, although the freight difference may be 10c to 15c on a ton against them. All these coals are high in volatile combustible, and therefore require furnaces with a large combustion space.

Walter T. Ray: Mr. Peebles asked about the deposition of soot and fine ash on top of the rear end of the middle baffle among the tubes, in Figs. 5 and 6. This does occur, and a little cleaning door has to be put into the setting at this corner. In this particular boiler that precaution was overlooked at the time of rebaffling, and in a few weeks the steaming capacity was found to be materially reduced.

Mr. Peebles also asked about the comparative rates of combustion of Clinchfield and Pocahontas coal with the same drafts in the furnace. On the face of it, the higher volatile content of

the Clinchfield coal does not seem to have aided its combustion.

The accompanying table, headed "Relative Rates of Combustion with the Same Drafts," shows that in general, Clinchfield coal burned a little faster than Pocahontas, notwithstanding its higher ash content in these instances; on an average, the Clinchfield ash ran about 10% as compared to 5% for the Pocahontas. The results obtained from the tests made by the United States Geological Survey, summarized in Bulletin No. 23 of the United States Bureau of Mines, showed that about 4% higher capacity could be expected from Clinchfield coal of 5% ash. On the average this means about one pound higher rate of combustion per square foot of grate surface per hour, which would put the higher-volatile Clinchfield's performance well above that of the lower-volatile Pocahontas in all cases excepting, perhaps, with the standard original baffling. It must be said, however, that the higher rate of Clinchfield's combustion was partly due to its containing much less slack.

RELATIVE RATES OF COMBUSTION WITH THE SAME DRAFTS.

ORIGINAL BAFFLING.

	"Drafts" in Furnaces, Inches of Kerosene.	Pounds Coal Burned per Sq. Ft. Grate per Hour.	Avg. of Preceding Column for Each Kind of Coal at Same "Drafts."	Percentages of Ash in Coals.	Avg. of Preceding Column for Each Kind of Coal at Same "Drafts."
Test No. 1, Poc.	0.375	22.0	23.6	3.64	5.19
Test No. 6, Poc.	0.375	26.0		5.32	
Test No. 7, Poc.	0.375	22.8		6.62	
Test No. 5, Clf.	0.375	24.6		7.70	
Test No. 2, Poc.	0.437	27.4	27.4	4.02	4.02
Test No. 3, Clf.	0.437	21.8	22.3	7.76	8.00
Test No. 4, Clf.	0.437	22.8		8.24	

HORIZONTAL TWO-PASS BAFFLING.

Test No. 8, Poc.	0.312	21.8	23.5	4.45*	4.72
Test No. 9, Poc.	0.312	22.7		4.45*	
Test No. 10, Poc.	0.312	23.7		4.45*	
Test No. 14, Poc.	0.312	26.0		5.50	
Test No. 11, Clf.	0.312	26.6	26.7	11.88	9.88
Test No. 12, Clf.	0.312	26.7		9.10	
Test No. 13, Clf.	0.312	26.7		8.66	

HORIZONTAL THREE-PASS BAFFLING.

Test No. 18, Poc.	0.188	21.7	21.5	4.96	5.22
Test No. 19, Poc.	0.188	20.2		5.48	
Test No. 17, Clf.	0.188	22.5	22.5	11.52	11.52
Test No. 16, Clf.	0.250	20.5	20.5	9.00	9.00
Test No. 15, Clf.		21.3	21.3	17.00	*17.00

*Too high owing to some mistake of sampling or analysis or stenography.

Mr. Naylor asked about the relative costs of evaporating 1,000 lbs. of water—neglecting labor, etc., I presume. The freight rate on Clinchfield coal to a representative central point, Columbia, S. C., is \$2.25 per short ton, and on Pocahontas, \$2.35. The 1913-14 contract prices generally prevailing on these two coals are respectively \$1.08 and \$1.25 per short ton, making the delivered cost of Clinchfield coal \$3.33 and of the West Virginia coals \$3.60. I have previously stated, in answer to a question from Mr. Bement, that all Clinchfield contracts carry a guarantee of a minimum of 14,000 B. t. u., but for the purpose of answering Mr. Naylor's question the values of these tests will be used, although they are against the higher-volatile coal. In the early part of the paper is a table from which I extract some of the

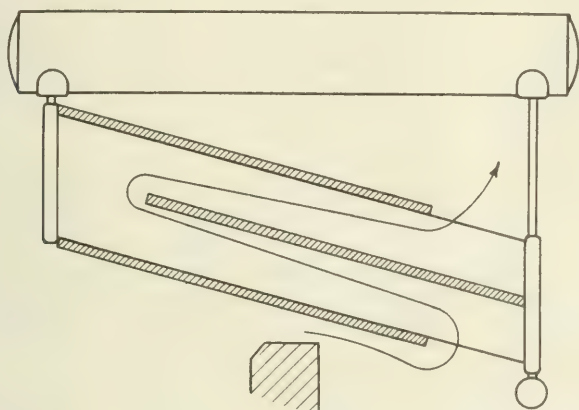


Fig. 17—Low Boiler Baffled Horizontally With Two Passes.

data to answer the question. The last line of the following table answers Mr. Naylor's question:

STANDARD ORIGINAL BAFFLING.

	Pocahontas Coal. Average of four tests.	Clinchfield Coal. Average of three tests.
Pounds, equivalent evaporation, per lb. of coal as fired	9.42	8.90
Cost in cents of one pound of coal delivered.	0.180	0.167
Pounds water evaporated for 1 cent's worth of coal	52.2	53.3
Cost in cents of evaporating 1,000 lbs. of water (for coal only)	19.1	18.7
Relative percentage cost of making steam....	100.0	98.0

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BOILER WITH TWO HORIZONTAL PASSES.

	Pocahontas Coal. Average of four tests.	Clinchfield Coal. Average of three tests.
Pounds, equivalent evaporation, per lb. of coal as fired	9.92	9.61
Cost in cents of 1 lb. of coal delivered.....	0.180	0.167
Pounds water evaporated for 1 cent's worth of coal	55.0	57.5
Cost in cents of evaporating 1,000 lb. of water (for coal only).....	18.2	17.4
Relative percentage cost of making steam....	95.3	91.1

BOILER WITH THREE HORIZONTAL PASSES.

	Pocahontas Coal. Average of four tests.	Clinchfield Coal. Average of three tests.
Pounds, equivalent evaporation, per lb. of coal as fired	10.33	9.97
Cost in cents of 1 lb. of coal delivered.....	0.180	0.167
Pounds water evaporated for 1 cent's worth of coal	57.4	59.6
Cost in cents of evaporating 1,000 lb. of water (for coal only).....	17.4	16.8
Relative percentage cost of making steam....	91.1	88.0

Mr. Kuss remarked on the comparatively low efficiencies of all the tests with the standard baffling. Such results are due to the fact that the boiler was only 9 tubes high, in consequence of which the gases passed through only 27 rows of tubes altogether. This is quite an independent consideration from any reduction of efficiency due to the small combustion space in the furnace.

A number of discussions of this paper have touched on the independent efficiencies of furnaces and boilers. The determinations of such efficiencies are still unreached goals, for engineers are not even agreed as to what the fundamental definitions are to be. Last winter I sent a discussion of the proposed new Boiler Testing Code to the December meeting of the American Society of Mechanical Engineers, but for various reasons it was never printed, to my knowledge. I therefore give here an outline of the method I there suggested for determining the true efficiency of a steam boiler as an absorber of heat by convection, regardless of how the gases are heated, or to what temperature. In a paper before this Society presented in 1907, and later published in several bulletins of the U. S. Geological Survey and the U. S. Bureau of Mines, Mr. Kreisinger and the writer substantiated fairly well Perry's theory that, beyond some certain capacity, every steam boiler has a practically constant efficiency of heat absorption by convection (not by radiation) and that this constant efficiency is a function of the physical conformation of the boiler, and is independent of the temperature of the water inside and of the temperature and the velocity of the entering

gases. This true boiler efficiency does depend, however, on the gas baffling of the boiler, for rebaffling a boiler, as was done in these tests, makes another boiler of it. Herein comes an opportunity to test far more easily than ever before the effect of baffle changes, so far as I can see now. Suppose we should take an unset water-tube boiler into an engineering laboratory and encase it tightly in a wooden board setting, making the baffles also of wood. It would be easy from time to time to change the baffling quickly into any other type desired. Fans could be arranged to blow atmospheric (cold) air through the boiler in any quantity desired. The water inside the boiler could be kept at any desired temperature by blowing live steam into it in several places, in such directions as to effect an energetic water circulation. If found necessary, propellers, actuated from the outside through stuffing boxes, could be added to make sure of having the water at the same temperature everywhere.

Now, if Perry's theory is as true as we believe it to be, the following equation ought to hold as well for heating up cold air while it passes through a hot boiler, as for cooling off hot gases while they pass through a (relatively) cold boiler:

$$E = \text{True Boiler Efficiency} = \frac{T_1 - T_2}{T_1 - T_w} = \text{Some constant}$$

percentage.

Where T_1 = temperature of the gases entering the boiler.

T_2 = temperature of the gases leaving the boiler.

T_w = temperature of the water (and saturated steam) inside the boiler.

Now, suppose a given boiler receives gases at a temperature of 2,300 deg. F. and discharges them at 1,100 deg. F.; and suppose the boiler water is at a temperature of 300 deg. F. (all this while working the boiler sufficiently hard to be on the horizontal or constant-efficiency part of the true-boiler-efficiency curve). This boiler, if perfect, would reduce the gases to boiler-water temperature, which is 300 deg., through a range of 2300 — 300 = 2000 deg. F. As a matter of fact, the true boiler efficiency is not 100%, as per the following equation:

$$\frac{2300 - 300}{2300 - 300} = \frac{2000}{2000} = 1.00, \text{ or } 100\%.$$

but it is as per this equation:

$$\frac{2300 - 1100}{2300 - 300} = \frac{1200}{2000} = 0.60, \text{ or } 60\%.$$

Now, it has been found, in the case of small laboratory boilers, and in the case of large commercial boilers, also, that

this ratio is approximately constant, so that if this boiler were fed with gases at any other temperature, and in any reasonable amount, the efficiency would figure out about the same. If the theory is sound it ought to work with cold air being heated up. Suppose this same boiler had its water contents kept at 300 deg. F., as before, and were supplied with air at 100 deg. F. If it were a perfect boiler it would heat up the air to 300 deg. through a range of 200 deg. Since its efficiency is only 60%, it will elevate the air temperature by 60% of 200 deg., that is, by 120 deg., or $100 + 120 = 220$ deg.

It is evident that such a method of experimenting on a boiler with cold air, or even with air moderately heated, as by a large number of small gas flames, offers an immense advantage in convenience and accuracy over the common method of using a coal fire, for the temperatures are low and easily measured with accuracy. The baffles may be of wood or any other easily-worked combustible material, and the setting equivalent may be cheap and removable lumber sides. A complete test could be run in a couple of hours, permitting of three or four tests a day. The baffling could be completely changed in a few hours.

Thus for the first time would we be able to ascertain the efficiency of a large commercial boiler rapidly and cheaply, and entirely independent of its furnace and with all sorts of bafflings. I have never had, nor do I expect to have, a chance to try out this method, and shall be glad to have anyone else investigate it. It may not work, and the theory may prove to be a mistaken one, but the reward is so great in case of success as to make the attempt alluring.

CHICAGO SUBWAYS

Presented September 8, 1913.

INTRODUCTION.

In view of the fact that the construction of subways in the city of Chicago is receiving at the present time a great deal of attention, the Board of Direction of the Western Society of Engineers have thought it advisable to have a discussion of the papers and reports that have been made at various times on this subject.

In carrying out this idea the Publication Committee have made abstracts of these various reports, which follow. In making the abstracts, an attempt has been made to be as brief and concise as possible, and yet cover all the essential features of each paper or report. It has been thought best to confine this discussion to the broad general principles of construction and routing, rather than to attempt to bring out fully the details of construction.

ABSTRACT OF REPORT RELATIVE TO THE CONSTRUCTION OF SUBWAYS.

BY GEORGE W. JACKSON, M. W. S. E.

September 19, 1904.

Mr. George W. Jackson was employed by the city of Chicago in 1904 as consulting engineer to the Council Committee of Local Transportation, to report on a general plan of construction of a comprehensive system of subways to be connected with the La Salle and Washington street tunnels when lowered. The report was submitted September 19, 1904, and has been followed by several printed reports and papers comprising discussions of the general plan, the details of construction and estimates of the cost of construction of an underground loop system for the city of Chicago, the relation of a passenger subway to subways for telephone and electric cables, water mains, high pressure water system, and a reconstruction of the loop sewer system, which form an important part of the papers and reports.

GENERAL DISCUSSION.

In the first report the author suggests that "Plans be drawn for a comprehensive subway of terminal loops to provide for the handling of all traffic between Michigan Avenue, Halsted Street and Chicago Avenue; my opinion being that if a traction subway is to be built it should be planned on the scale to meet the city's future needs."

A preliminary report with plans and the estimated cost of six loops of underground subway for the city of Chicago proposes to accomplish the following:

First. An underground subway system making it practical and serviceable to put in operation the one fare system without the issuing of transfers.

Second. An underground subway system without any so-called grade crossings at intersections.

Third. An underground subway system which becomes practical for cars from the different divisions of the city, to be routed to whatever division of the city they may be directed without grade crossings.

Fourth. An underground subway system which provides a ten-foot walk its entire length, enabling passengers and pedestrians to walk underground to any station they may desire to reach without coming to the surface, as well as having a continuous landing for passengers to leave or gain access to cars and preventing congestion.

Fifth. An underground subway system which makes it practical to install and operate on large radius curves at intersections, and at the same time have the necessary room for the placing of the different corporation utilities, which become a very important factor in designing a serviceable and practical subway for the accommodation of street cars and corporations' and city's utilities.

Sixth. An underground subway system which provides practical space for the placing of appliances of the different corporations operating under license from the city council, as well as space for new utilities which the city government may wish to install, and at the same time leave space enough for the future development of our city to an extent way beyond the most sanguine hope of the growth of the city.

Seventh. An underground subway system which would take care of our present unsanitary sewers, as well as make provision for the taking care of new sewer systems in connection with a high pressure water system which should be built at once in connection with a new storm-water sewer system, and also making provision for the economical and speedy way of making connection from the different corporation systems to buildings along the line of subways.

Eighth. An underground subway system which will not require the city or property owners going to the large expense of removing the different appliances which have been installed under our sidewalks, as well as taking care of and making it practical and possible to construct a subway without the city assuming a possible large liability caused by the settlement of buildings during the construction of the subway.

SUBWAY LEVELS.

"The business district of Chicago is bounded on the south by Twelfth Street, on the north and west by the Chicago River, and Lake Michigan on the east; the space underneath the streets is occupied by the different corporations with ducts for the placing of their cables and necessary manholes for handling the cables. This

with our present sewer system, water mains, and gas systems, forms a network underneath the streets extending down to about 12 ft. below grade. All of these systems in my judgment will have to be rearranged.

The grades of our streets have been changed from time to time until at the present time the streets have been raised and filled in for a depth of about ten and one-half feet. This fill was made mostly from the refuse of the Chicago fire of 1871. Below this ten and one-half feet there is a deposit of about two and one-half feet of loamy soil. This soil is water bearing. About four feet below this stratum or loam there is a deposit of what is known and termed as mud. Below this point clay is encountered. This deposit of clay becomes drier and runs uniform until what is known as hard pan is encountered. This is the nature of the deposit in Chicago as far south as Congress Street. South of Congress Street the deposit runs very irregular, being composed of sand, clay and gravel, a large part of it being water bearing."

SUBWAY ROUTES.

The routes of the proposed subways are shown on Plate I. Three double-track looped routes are provided for the South Side, two for the West Side, and one for the North Side of the city.

ESTIMATE OF COST.

Total cost of 50,703 lineal feet of subway including all routes with all the necessary appurtenances..	\$15,610,197.00
Purchase of property	1,250,000.00
Engineering and omnibus expenses 7%.....	1,092,713.79
Incidental expenses, labor, insurance, accidents and possible damages, 4%.....	624,407.88
Grand Total	<u>\$18,577,318.67</u>

"In estimating the cost of construction I have taken into consideration the construction of stations, repaving of the streets, the construction of a practical underground conduit system for trolley purposes, the placing of pipes and cables which now occupy space in the streets, as well as taking care of the city's present utilities."

ABSTRACT OF PAPER ON "THE PROPOSED INNER CIRCLE OF CHICAGO SUBWAY TERMINALS"

BY ARTHUR S. ROBINSON, M. W. S. E.

September 16, 1906.

Mr. Arthur S. Robinson presented a paper before the Western Society of Engineers, Sept. 16, 1906, with the following title: "The Proposed 'Inner Circle' System of Chicago Subway Terminals."

November, 1913

The keynote was struck in the second paragraph which read:

"The particular feature of the problem that interests me most and the one to which I desire to call attention in this paper, is the downtown terminal facilities."

The author believes that the space below the streets presents the only remaining and untouched opportunity which will be the solution of the traffic problem of the city. No claim is made that the solution lies in what he presents, but he believes his plan has a number of features to recommend it, which features he hopes may be deemed of enough value to be incorporated in the final plans.

The ability of any railway system to handle its traffic depends more than anything else on its terminal facilities, and a proper terminal system for the Chicago Subways is the desideratum to be striven for. To the author the system finally adopted must be in the form of the loop.

The underlying principle of the scheme presented by the writer is the idea of an inner loop transfer track, surrounded by an outer loop, composed of the connected loop ends of the diverging lines and separated from it by a continuous platform between them.

The general plan of the proposed system is shown on Fig. 1 (vide *Journal W. S. E.*, page 581, Vol. XI, Oct. 1906). The inner loop has trains for carrying passengers to stations so that in any one loop the maximum distance to be walked by any passenger from his place of business to a subway station will be limited to one and one-half blocks. The small loops connected to the outer track are loops of independent systems. A passenger walks to the nearest subway station, takes a car on the inner loop and rides to a station opposite the loop of the line he takes to his home. He merely steps from the local loop car to the platform, crosses it and steps into the car which will carry him beyond the business district. Coming into the business district it will be necessary to make a change from the outer district cars to the inner loop local cars.

A transfer across the intervening platform is not necessary except for those who prefer to ride to a point very near their places of business; stations being opposite loops of outer district cars. Few passengers perhaps would ride more than two or three blocks. All entrances to be on the platform and the inner loop cars to be open only on the platform side and moving in a direction contrary to that of the outer district cars. The author uses the term "Inner Circle" for the local cars and the term "Division Loops" for the terminals of the outer district lines.

The claims of the author are summed up as follows:

"The features wherein I believe this 'Inner Circle System' excels, are: the greatest possible capacity for the limited area; all subways to be on the high level, thus giving least stairway distance; the possibility of easy through traffic ar-

rangements; the unification of all street railways under a single operating management, at least so far as the transit through the downtown district is concerned; the safety of passengers and rolling stock; simplicity of arrangement whereby its operation is easily understood; simplicity of operation, for each line operates its own loop; rapidity of service, for it is possible to operate on the least possible headway dis-

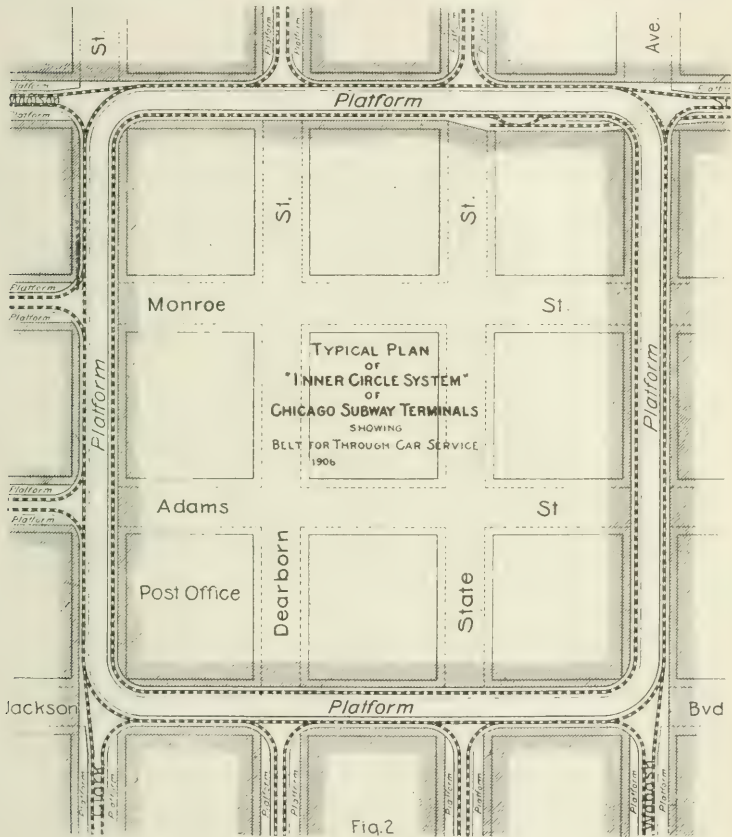


Figure 1—A. S. Robinson

tance; accessibility since the subway entrances may be located at as frequent intervals along the street as the traffic demands; and above all the total absence of grade crossings; and the highly important feature that all cars of the connected systems move in the same direction, thus securing absolute immunity from head end collisions, and a majority of other classes of accidents."

The author goes into necessary detail relating to construction work; arrangement of stations, and adaptation of existing tunnels to the "Inner Circle System" but such detail may well be omitted in this abstract, the reader being referred to the original paper if interested in more than the plan proposed.

ABSTRACT OF PAPER ON A SHUTTLE SYSTEM FOR CHICAGO SUBWAYS

BY ARTHUR S. ROBINSON, M. W. S. E.

February 8, 1911.

Mr. Arthur S. Robinson presented a paper before the Western Society of Engineers February 8, 1911,* with the following title, "A Shuttle System for Chicago Subways."

The author refers to a previous paper he presented in September, 1906, on a system of terminal loops for Chicago subways, and proceeds to offer the shuttle system for the consideration of the public, as tending to remove the principal objection to his loop system, *i. e.*, centralization of travel, tending to congestion, rather than distribution.

The primary object of subways is the rapid movement of the street cars in the business district, so all surface lines should be removed to subways having a minimum of curvature, no grade crossings, an absence of steep grades, as many stations as possible having long platforms, and all cars and trains to move in the same direction on their respective tracks. These things the author believes will be accomplished by the adoption of a system of through route loops, as distinguished from terminal loops, and the system is in no sense a terminal system.

The paper is accompanied by eleven drawings, three being maps. The initial installation of subways is shown on the first map and contemplates the use of the Van Buren Street, Washington Street, and La Salle Street tunnels. The second map shows the completed installation of the subways, showing double tracks only, for the sake of clearness, on all streets occupied.

Whenever the width of streets will permit, four tracks should be built: the inside tracks to be connected by cross-overs with their respective main tracks, and used as passing tracks to advance loaded cars around stations at which cars are receiving. If the width of the street will permit of three tracks only, the middle track should be separately connected at about the dividing line between the north and south bound traffic with its main line and used for the same purpose. The proposed routing is suggestive.

An inspection of the map shows that Chicago would be divided, for transportation purposes, into practically two sections,

*Journal, W. S. E., Vol. XVI, No. 3, March, 1911.

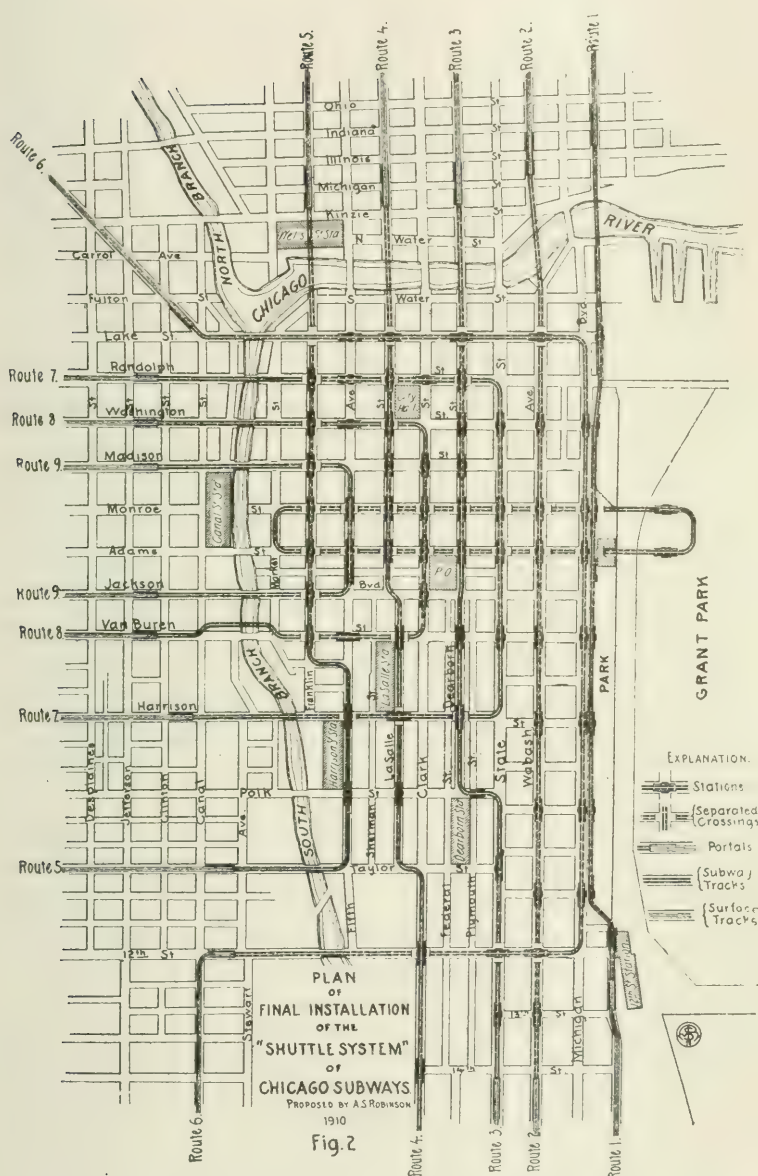


Figure 2—Robinson's "Shuttle System."

the north and south, with the imaginary line of demarcation on Monroe or Adams Street. It is intended that the loop line shown on Monroe and Adams Streets, if found desirable to build, would act as a transfer only, and would be the only line of the system having stations on the lower level.

An inspection of the profiles shows that all the stations, on all lines, except the transfer line, will be on the upper level. In order to avoid grade crossings, one of the lines is carried under the other at street intersections, coming again to the upper level as rapidly as possible within the limits of maximum grade, which is determined by tunnel approaches, thus putting the stations on the west side lines on the upper level, and the same minimum stairway distance below the street surface as the north and south lines.

These are the characteristic features of the system and the ones the author of the paper emphasizes. As no station is contemplated at the street intersections, for the lower line, the existence of the crossings will not be appreciable to the passengers on either line or either level.

By introducing separated grade crossings in this manner and bringing the cross-town lines from the west side to the upper level, with all passengers from all parts of the city on the same stairway footing, no division of the city is handicapped by having to use stations on the lower level for direct communication, because in this way the lower level subway, as such, with its attendant objections would not be necessary.

It is assumed the full width of the street will be occupied, or so much of it as may be found necessary to provide for the subway and also all public utilities. The deep excavations will be confined to the street intersections and to the transfer line on Monroe and Adams Streets. Including the transfer line, this makes the deep excavation approximately 17% of the total length of excavation; without the transfer line less than 10%.

A characteristic feature of this shuttle system is that it is a combination of ten short units or independent routes, each complete in itself. Any one or more units may be built at any time as traffic demands, thus affording its proportion of relief immediately upon completion, the ten routes together making a system by which every street in the business district is reached from all parts of the city with the least effort.

ABSTRACT OF REPORT ON PASSENGER SUBWAY AND ELEVATED RAILROAD DEVELOPMENT IN CHICAGO.

BY CHARLES K. MOHLER, M. W. S. E.

October 8, 1911.

Mr. Charles K. Mohler was employed in 1911 by the City Club of Chicago as consulting engineer, to make recommendations concerning the development of certain elevated railway and subway

facilities. His report was submitted to the City Club on October 8, 1911, and the City Club transmitted it to the Committee on Local Transportation of the City of Chicago on May 11, 1912.

Mr. Mohler attended the various public hearings on the question of subways held before the Committee on Local Transportation of the City Council during the spring and summer of 1911, at the request of the City Club, and his report is based largely upon the information and suggestions presented at these public hearings.

The following is a brief abstract of the main features of Mr. Mohler's report, and includes his recommendations regarding the construction of subways.

GENERAL DISCUSSION.

The report considers the transportation problem under two separate headings, first, "Surface Lines," second, "Elevated Lines." Regarding the surface lines, the report contains the broad statement that by through routing "the same occupancy by cars on the trackage inside of the business district during the rush hours would furnish facilities for taking out or delivering double the number of passengers now carried in a given time." The report also contains a statement regarding the elevated lines, "that with complete through routing the capacity of the loop would be increased from 735 cars per hour to 2200 cars per hour."

Considering proposed betterments of the transportation situation, the following conclusion is reached: "The routes selected should be those which can be constructed at the least expense, relieve congestion, follow the most direct lines, with the least turns and curvature, eliminate the greatest number of grade crossing interferences, and offer facilities for enlarging rather than restricting the delivery territory." The conclusion is reached in the report "that many of the proposed means of remedying the congested condition would ultimately if not immediately lead to still greater congestion."

The traffic demands of the city are growing at such a rate that added facilities must be provided not only for the surface lines but for rapid transit lines, or the development of additional facilities by means of A, Subways; or B, elevated railroads.

A—SUBWAYS.

In considering the routing of subways, the subject is divided into surface car subways and rapid transit subways.

Surface Car Subways. The plan of the proposed surface car routing is shown on Plate II. The four routes are as follows:

First. A line in Lake Street east from Halsted Street, with a branch from Milwaukee Avenue, to Michigan Avenue, thence south in Grant Park to Harrison Street, thence west in Harrison Street to Halsted Street and Blue Island Avenue.

Second. A line under Clark Street, connecting Lake Street and Harrison Street.

Third. A through north and south subway in Clark Street.

Fourth. A subway from the North Side running south under Grant Park to connect with Indiana Avenue at 18th Street.

Rapid Transit Subways. The rapid transit subways planned for the business district contemplate connections with the present elevated lines or with new elevated lines to be built over the rights-of-way of steam railroads. The routes in the Loop district as planned comprise north and south lines in Grant Park east of Michigan Avenue, in State Street, and in Fifth Avenue. A line from the West Side is also planned in Lake Street, Grant Park and west in Van Buren Street.

The above additional trackage in the business district is required to secure the terminal capacity so that the main stem of the transportation system connecting with the outlying district may be brought up to somewhere near its maximum capacity.

"To secure this added trackage in the congested district for both rapid transit and surface lines, it can probably best be had by the construction of four and three-track subways wherever possible in substantial accordance with the routes outlined above, for the following reasons:

1. If the present business district is enlarged and the whole is developed on the basis of twenty-story buildings or higher, the demands for transportation facilities may become such as to require a four-track (or all that it is possible to build) in practically all of the downtown streets in order to afford adequate trackage and loading and unloading facilities.

2. A four-track subway in every alternate street will afford about the same capacity as a two-track subway in every street *with only one-quarter the number of low level crossings.*

3. While the construction of a four-track subway will probably be attended with greater danger and damage to buildings, there will be only one-half as many of them subject to damage, and one-quarter as many low level crossings.

4. Only one-half as many streets will have to be torn up with the destruction and required renewal of paving, underground construction, such as sewers, water and gas pipes, wire conduits, etc.

5. With double track construction, a heavy side wall will be required for each track, while with four-track construction only one wall will be required for two tracks. In fact, when the building foundations are properly taken care of there is perhaps little reason why the entire space between building lines cannot be excavated and the necessity for side walls entirely removed, at least for high level subways opposite the more recently constructed buildings. As there would preferably be no station platform in the low level portion of subways, the width would be reduced to the least possible and the field of operation would be removed to some distance from building foundations in eighty-foot streets.

6. Only one-half the number of business places would be interfered with and suffer business loss and damage in securing a given track capacity with four-track subways in alternate streets as against only two tracks in each street occupied.

7. By building the suggested four-track subways at the highest possible level in every-other street for half their length, the other half being made up of approaches to and from an under crossing with an intersecting subway, it would be possible to build subways in all intervening streets if developments proved them to be a necessity at any time in the future. In other words, build two blocks continuously at the same level, and each incline approach one block long to cross under another subway. While that would require a larger proportion of the future subways to be built at a lower level than those first constructed, still there would be this advantage, that many more of the buildings now on insecure, shallow foundations will be replaced with the deep foundation type.

8. The time required for construction to obtain a given track capacity should be much less if secured through four-track construction in alternate streets than it would be by the construction of two-track subways in every street.

9. Although, as previously pointed out, the danger and damage to buildings would probably be greater with four than it would be with two-track construction, it is still believed for the reasons stated that the actual cost per mile of single track should be considerably less.

It may be that in many cases where the excavations are to be carried past old buildings, that would be in danger on account of their insecure foundations, arrangements could be made with the owners to put in permanent deep foundations which would serve for the heavier new buildings which are almost certain to be constructed in time."

SUBWAY LEVELS AND GRADES.

"On account of the soft, putty-like material underlying the streets of Chicago, it is desirable, if not essential, that the depths of subways should be kept at the highest possible level. It is believed that the requirement for keeping them at the least possible depth can be accomplished best by alternating the crossings, so that instead of maintaining a constant low level for either the east and west or north and south lines, either system will be at high or low level at any particular intersection to best suit the conditions to be met.

"Very material added advantages which might be derived from undulating grades would be that on approaching a high level station, the up-grade would assist in bringing the train to a quick stop. On the other hand, the down grade on leaving the station would be a very decided aid in accelerating the cars or trains and gaining in operating speed and efficiency.

"If all stations were made at the high level, they would be more accessible than low level stations."

B—ELEVATED LINES.

Before the final adoption of subway routes is decided upon, the author believes there should be made a thorough investigation of the possibilities which may be developed in the rapid-transit situation by building elevated lines adjacent to, or as second story structures over, certain of the steam railroad rights-of-way. A number of routes are described and shown on Plates II and III. Plate III shows the additional territory that would be tributary to such lines.

These lines are simply suggestions to point out the possibilities that may be developed. The cost for constructing elevated roads over such trackage as outlined would probably be more than ordinarily required for building in a street or over private right-of-way, but the damage claims should be little or nothing, and the whole would unquestionably be only a small fraction of the cost required for the construction of subways. When account is taken of the decided saving in cost of this kind of construction over that required for the construction of subways, and the fact that little or no additional damage is caused to adjoining property and the comparative ease and facility with which the construction may be carried out, it is believed this should receive serious consideration. For long-haul rapid transit on a five-cent-fare basis, the expenditures for right-of-way and construction must be kept on the lowest possible basis to reduce the fixed charges and prevent them from becoming too great a burden for the traffic to support.

ESTIMATED COST.

The author believes that many of the estimates of cost of subway construction in Chicago are too low. The following costs are quoted from an article of Wm. S. Twining, formerly Chief Engineer of the Philadelphia Rapid Transit Co.

	Per Mile of Route—Double Track	
	Lowest Cost	Highest Cost
Surface line, trolley	\$ 30,000	\$ 50,000
Open floor elevated	300,000	400,000
Solid floor elevated	550,000	700,000
Subways	2,000,000	4,000,000

The total mileage and estimated cost of the rapid transit lines as planned in this report are as follows:

	Miles Double Track	Cost
Surface car subways	8.38	\$29,740,000
Rapid transit subways	11.23	43,030,000
Rapid transit elevated lines	20.30	10,150,000
Total	39.91	\$82,920,000

ABSTRACT OF REPORT OF TRANSPORTATION SUBWAYS BY COMMITTEE ON LOCAL TRANSPORTATION, CITY COUNCIL OF THE CITY OF CHICAGO.

JOHN ERICSON, M. W. S. E., AND THOMAS T. JOHNSTON.

January 2, 1909.

This report was made January 2nd, 1909, in pursuance of a resolution of the City Council directing the Committee on Local Transportation to proceed with the collection of data and investigations in relation to the construction of transportation subways within the area bounded by Chicago Avenue, Halsted Street, Twelfth Street, and Lake Michigan.

The report contains a large amount of data bearing upon the subway problem and also the closely related matter of accommodating the public utilities, water, sewer, gas, and electricity within the district included. The consideration of these matters is closely related to the subway problem, on account of the necessity for maintaining the public utility service within the district during the construction of subways, and further, aside from subway construction, a comprehensive plan for accommodating these utilities within the streets as needed.

GENERAL SCHEME.

A tentative plan for accommodating the needs of the present and near future is shown upon Plate IV. This plan contemplates a high-level subway to accommodate both surface and elevated transportation, particularly the traffic originating outside of the subway district. It is not proposed to supersede the surface transportation entirely within the district. The subways occupy the space between the street curbs and accommodate the public service utilities, water, sewer, gas, and electricity in conduits beneath the tracks.

The following extracts from the report further explain it and give some reasons for the tentative plan suggested.

PROVISIONS FOR TRAFFIC.

The statistics of traffic show that the number of passengers to be carried in a city increases faster than the population. That is, if the population is doubled, more than double the people are to be carried, and as the need of access to the business district will keep pace with the growth of the city, then more than double the passengers will desire to pass back and forth from the business district when the population has doubled.

It may be inferred, from a study of the water supply for the November, 1913

business district, that the requirements for transportation in this area will be at least quadrupled in the next 30 or 40 years.

RELATION TO BUILDING FOUNDATIONS.

The nature of the soils in which construction of subways must be made, demanded an investigation of building foundations.

It is believed that the construction of low-level subways, such as will be required under the rivers, could not be constructed throughout the whole or any considerable portion of the business district along the lines according to which they may be located, because the items of large expense, and instances where special constructions would have to be used, would become so numerous as to render the total cost of the whole work prohibitive, to say nothing of the great length of time that would be required to do the work.

PROCEDURE IN CONSTRUCTION.

While the studies of this subject have not progressed to a conclusion, it seems likely that a four-track subway north and south, at the eastern side of the business district, and extending from the vicinity of Chicago Avenue and Orleans Street to the vicinity of State and Twenty-second Streets, will be desirable, and that contemporaneously with or following this first undertaking, two east-and-west subways may be made, one reaching a terminal in the vicinity of Halsted Street and Blue Island Avenue, and the other reaching a terminal in the vicinity of Lake and Halsted Streets. These West Side terminals will provide for collecting traffic of the Metropolitan Elevated Railroad and the Lake Street Elevated Railroad, and also a number of surface lines now converging close to these points.

A general scheme is thus presented for early subway construction, the details of which are subject to further study. The essence of the arrangement is the location of subway terminals, four in number, on each of the four elevated railway lines at the margin of the business district, and which are also located at points of close convergence of a large number of surface lines. A large provision for future traffic requirements will thus be brought about, and as a necessary consequence the carrying capacity of the existing transportation lines or their equivalent outside of the business district will be accomplished.

LOCAL TRAFFIC.

The complete removal of the local transportation lines from the street surface is at least unlikely, as there will be increasing need for such lines to transport passengers over short distances within the zone and to some extent without the zone. It may be said in general, that, in view of the fact that subway transportation cannot ultimately meet the requirements that will follow the present order of development, the use of subways, while providing as fully as possible for purely local traffic, should

be for the outlying residential districts, rather than that comparatively minor traffic pertaining to the short distances within the subway itself.

CAPACITY.

As a means for relief of congested traffic, it may be said that if a subway run from Chicago Avenue and Orleans Street at the north to State and Twenty-second Streets at the south, along a route following Wabash Avenue through the central business district, and if two of the tracks be used for the movement of trains from the elevated railways, and two for the movement of surface line cars, then its capacity for comfortably carrying passengers will be 18,000 per hour in each direction on the tracks devoted to the movement of surface cars, and 25,000 passengers per hour in each direction on the tracks devoted to moving elevated trains.

This contemplates the movement of 240 cars per hour on the tracks devoted to surface lines, and 50 trains, each of seven cars, per hour on the tracks devoted to the elevated lines, making a total carrying capacity of 86,000 passengers per hour, or not far different from either the present carrying capacity of the combined elevated roads or combined surface roads in their present state of congested traffic. In other words, it will add 50% to the carrying capacity of the local transportation lines.

The passengers who will contribute to this traffic will be made up, firstly, of that element escaping from the existing congestion; secondly, of that element of traffic that will come into existence because of additional transportation facilities; and thirdly, from the increase in traffic that will naturally take place between the present time and the time when the subway can be placed in operation. It is quite probable that if one subway alone be constructed, it will be found to be carrying passengers to its comfortable capacity as soon as completed, without in any great degree relieving the present state of congestion.

If the subway here described is constructed, and other subways be built east and west to terminal points on the Metropolitan Elevated Railroad at Halsted Street and Blue Island Avenue, and on the line of the Lake Street Elevated Railroad at Halsted and Lake streets, as much more capacity for transportation will have been created, with the probability that the combined subway construction thus outlined will give, for the time being, relief from existing congestion.

The combination of subways thus suggested cannot be expected to provide adequate transportation facilities for any considerable future period, and their construction must be followed substantially at once by subways taking advantage of other outlets from the business district.

ESTIMATES OF COST.

Inasmuch as the investigations had not been entirely completed at the time of presenting this report, total estimates of cost were not given further than the following estimates of cost per mile.

It is estimated that the cost of making subways, excepting such costs as will pertain to foundations of buildings, will be as follows:

	Cost per Mile
Four-track subways, as in Wabash Avenue.....	\$3,750,000
Three-track subways, as in Washington Street.....	3,375,000
Two-track subways, as in Van Buren Street.....	3,000,000
One-track tunnels, as under the rivers.....	800,000

The cost of taking care of building foundations will depend on the method of procedure in doing the work; it is believed, however, that a specification for doing the work may be drawn, under which contractors will agree to execute the work at the prices above estimated, and without extra charge for caring for building foundations.

An estimate for caring for building foundations along the north-and-south line suggested is \$200,000 per mile under one form of specifications. It is only in the business district that any considerable costs of this nature will be involved; and while an occasional large building on spread foundations (like the Auditorium) may individually involve much larger expense, it is believed that the cost per mile as estimated, when distributed over the entire proposed line, will not be exceeded.

ABSTRACT OF JOINT REPORT ON COMPREHENSIVE SYSTEM OF PASSENGER SUBWAYS FOR THE CITY OF CHICAGO

BY THE HARBOR AND SUBWAY COMMISSION AND SUB-COMMITTEE
OF THE COUNCIL COMMITTEE ON LOCAL TRANSPORTATION.

September 10, 1912.

The Harbor and Subway Commission of the City of Chicago, under specific instructions from the Local Transportation Committee, on February 19, 1912, submitted tentative routes for an independent system of municipal subways extending to the city limits on three sides.

Later the Local Transportation Committee requested more comprehensive plans for municipal subways, which would be entirely independent of and supplementary to, all existing means of transportation. The Subway Commission and a Sub-committee of the Local Transportation Committee submitted, on September 10, 1912, the following report on the selection of routes for a comprehensive municipal subway which would bring Chicago transportation facilities up to the standard demanded by the city's growth.

Traffic demands, per capita, are constantly increasing with growth of population. In ten years the average number of rides per capita, in Chicago, has increased from 200 to 300. If population continues to increase in the same ratio as in the past, the proposed subway system is needed to take care of new traffic, besides relieving present congestion.

In its financial aspect, the scheme of a comprehensive municipal subway system for Chicago is worked out on the theory of New York's experience, that the capital cost of construction can be fully provided out of future earnings, and not from any charge on the Chicago taxpayers.

The routes submitted are on the basis of absolute municipal ownership and control of the leading arteries within the city limits. They are laid out on trunk lines, with connections and extensions to unite the whole city, relieve immediate traffic congestion, and permit of future expansion.

These subways will have a beneficial effect on real estate and commercial interests generally.

The one-city-one-fare idea has been followed throughout, with universal transfer and ride from anywhere to any other place in a continuous line for five cents.

While possibility of profitable operation has been considered, the best interests of the people are to be served, and the subway system, as planned, is to go to all sections of the city, and tend towards the symmetrical building up of these sections by genuine rapid transit. A municipally owned subway system can afford to support, for a time, the less profitable extensions out of the surplus earnings of those routes that extend through richer and more populous territory.

Endeavor has been made to avoid constructional complications, and plans so designed that the least expensive method of operation is the most effective method.

A high level subway, located as close as possible to the surface of the street, has been aimed at throughout. All grade crossings are avoided, and the only deviation from high level will be at intersections and under river.

For ventilation, the piston action of the trains is utilized, with a sufficient number of openings through the roof and the sides of the subway.

Centrifugal fans also to be placed in subway. These are needed in case cars get stalled, and for quick removal of smoke in case of fire.

No definite plans for provision of utilities. These may be diverted or placed in space not required for subway use. The Public Service corporations would rather have their own conduits than pay proportion of cost of a compartment in the subway.

SUBWAY ROUTES RECOMMENDED.

The subway routes as recommended are shown on Plate V. The lengths of all routes, with the number of stations proposed, and running time for local and express trains are shown in the table below:

Terminal.	Route.	No. of Station Stops.	Length of Subway. Miles.	Number of Tracks.	Time for Express Trains.	Time for Local Trains.
Lawrence Ave.	Evanston Halsted Clark	13	3.1	2	18.7 min.	21.8 min.
Lawrence Ave.	Lincoln Clark	14	3.42 3.6	4 2	20.4 min.	23.5 min.
Kedzie Ave.	Elston Ave. California Ave. Milwaukee Ave.	16	2.5 5.25 1.8	2 2 2		26.3 min.
40th Ave.	Armitage Ave. Milwaukee Ave.	15				24.0 min.
40th Ave.	Madison St.	10	4.8	2		16.3 min.
40th Ave.	26th St. 22nd St. Blue Island Ave. Harrison St.	14	6.8	2		23.0 min.
Western Ave.	55th St. So. State St.	20	3.0 6.0	2 4	25.7 min.	31.4 min.
79th St.	Cottage Grove 55th St. So. State St.	22	4.15	2	29.3 min.	34.9 min.
From Fullerton Ave. to 79th St.	Halsted St.	24	12.0	2		40.2 min.
Total			56.42			

The capacity of the subway system outlined in this report is estimated to be 180,000 seats per hour.

ESTIMATED COST OF SUBWAYS.

North Side to Lawrence Avenue	\$ 20,123,000.00
South Side to 79th Street	25,778,000.00
West Side to 40th Avenue.....	31,049,000.00
Halsted Street	19,307,000.00
	\$ 96,257,000.00
Estimated Cost of Equipment	34,844,000.00
Total	\$131,101,000.00

The equipment will be furnished by Operating Company.

"The estimates of cost of construction submitted in this report cover all necessary excavation, and concrete, brick and steel construction, the bracing of excavations, maintenance of limited or controlled traffic in one-half the width of the streets within a distance of three miles from the intersection of State and Madison streets, the shoring and bracing necessary to maintain the level of

buildings and the restoration of street paving and surface track construction, also temporary construction to maintain sewer and water service and fire protection during the time of partial obstruction of the street."

"In the territory over three miles from the intersection of State and Madison streets, it is expected that traffic may be diverted to other streets and alleys during the period of subway construction."

"The power system, contemplated for subways, comprises alternating current generation and distribution, and direct current operation of car motors. In other words, power will be distributed from the central station at high potential to sub-stations, located as near as possible to center of demand, where this power will be transformed and converted into direct current at potential of 625 volts. Estimates were based on third rail direct current system of conductors."

"The type of car contemplated for use to be of steel construction with enclosed vestibules and sliding doors, with an approximate seating capacity of 60 passengers."

"A complete system of automatic block signaling and interlocking adapted for efficient spacing and directing of trains is contemplated."

"With the type of equipment and the schedule speed contemplated, the preceding tabulation indicates the time that will be required for a given subway train to traverse the distance between its outer terminal and a point in the center of the city, approximately State and Madison streets."

The Subway Commission consisted of Mr. John Ericson, Mr. James J. Reynolds, and Mr. E. C. Shankland.

The Sub-committee of the Local Transportation Committee was composed of Mr. Eugene Block, Chairman, and Messrs. John A. Richert, Patrick J. Carr, William F. Schultz, William J. Healy, Henry D. Capitain, and Charles Twigg.

ABSTRACT OF REPORT ON THE ENGINEERING AND OPERATING FEATURES OF THE CHICAGO TRANSPORTATION PROBLEM.

BY BION J. ARNOLD, M. W. S. E.

November, 1902.

Mr. Arnold was employed by the Local Transportation Committee to report on the general transportation problem of Chicago especially as it related to the surface railroads, and was requested to make recommendations on over twenty specific questions relating to valuation, earnings, design, routing, etc.

The following is a brief abstract of the main features of Mr. Arnold's report, with regard to the general transportation problem, and of his recommendations regarding the construction of subways:

November, 1913

GENERAL DISCUSSION OF STREET RAILWAY SYSTEM AND CONDITIONS GOVERNING THEM.

"Nearly all of the large cities of the United States are laid out and developed on one of three distinctive plans, each plan requiring a different general system of transportation routes to serve its population.

First. The peninsula plan, with water front on both sides such as that of New York City and San Francisco.

Second. The valley plan, with a river running through the center, population and business district on both sides of the river, such as Pittsburgh.

Third. The radiating plan, with territory on one side of the water front, such as St. Louis, Boston, Brooklyn and many other cities. To the third plan Chicago belongs.

The peninsula and valley plans usually call for comparatively small street railway track mileage, and great traffic density is found on that mileage, together with large gross earnings per capita served, per mile of track and per car mile.

The radiating plan means greater street railway mileage for the population served, with much smaller gross receipts per capita.

Population and population density have an enormous influence on street railway earnings and profits.

A knowledge of these differences in city plans and their bearing on the earnings of transportation companies is so absolutely essential to the proper understanding of the theory of conducting transportation, that this brief explanation is deemed advisable.

EFFECT OF DIVISIONAL LINES ON CHICAGO'S DEVELOPMENT.

While Chicago has been classed among those cities laid out on the radiating plan, and, consequently, is one of those cities wherein an ideal system of transportation is difficult of attainment, an added obstacle to such realization is found in the fact that the city is divided into three divisions by the unfortunate course of the Chicago River.

As is the case in all cities laid out on the radiating plan, Chicago has a common point where all lines of traffic concentrate and which is the objective point of its population, commonly designated as its business center. This point was fixed and has grown up, by and from the causes outlined above, and must be considered in a large degree as governing the transportation situation.

It is true that as the area of the city grows and population increases, new centers are created at different points in the separate divisions, around which centers population masses, and there is a growing demand for transportation between divisions, without reference to the general downtown business center. This demand, which did not exist in the infancy of the city when there was only one business center, will continue to grow as the city grows, and as former residents of one division move to other divisions, and

carry with them the desire for communication with their former neighbors.

PROBLEMS TO BE SOLVED.

The problems to be solved in relation to transportation facilities for the whole of Chicago and its suburbs are, therefore:

First. To devise some method of operation which will relieve the congestion of the overcrowded thoroughfares in the central portion, or business district, of the city and tend to render available an increased area in that district.

Second. To furnish a more ready means of intercourse between the separate divisions of the city, through the business district and outside such district.

Third. To furnish a means of distributing passengers brought in at the several railroad stations, for transferring them from one station to another, and to facilitate intercourse between different portions of the business center.

UNDERLYING IDEAS OF REPORT.

Viewing the situation from the standpoint of the best interests of the whole city of Chicago, these ideas should prevail at all times and be guiding and determining factors in arriving at conclusions, viz.: That Chicago is one city, not three; that there are no divisional lines traversing the district embraced within its boundaries; that the citizens have the right to expect and demand that they be transported in, through, and about the whole district in one general direction for one fare and with as little inconvenience attendant upon the use of transfers as practicable. With these ruling ideas held firmly in mind, this report has been formulated.

In my opinion, in the adjustment of this transportation question, the amount of cash compensation to be secured by the treasury from the street railways should be of secondary consideration to the attainment of one fare within the city limits, and the very best transportation facilities known at the present time, with the guaranteed assurance that the service be kept up to modern standards and that the citizens would receive all the benefits from all future developments of the art.

DISCUSSION OF A NEW, REORGANIZED AND UNIFIED SYSTEM OF STREET RAILWAYS FOR CHICAGO.

I have been asked to formulate a plan of surface transportation for Chicago, treating the situation as if all divisional lines were eliminated and as if the Chicago City Railway Company and the Chicago Union Traction Company were under one ownership and one operating management,—transporting passengers for one fare throughout the territory at present served by both companies.

November, 1911

RELATION OF UNIFICATION TO THE SUBWAY QUESTION.

If subways were built for the accommodation of cars operated under the present divisional plan, with the eliminating of grade crossings held in mind, the subway system would naturally consist of a number of small loops, disconnected, and entering from each division.

Logically, subways designed to avoid and decrease congestion should pass through the long way of the congested district in order to perform the greatest service.

Following this course of reasoning, my recommendations are for north and south subways between Fourteenth Street and Indiana Street, and in one plan hereinafter outlined, with connections to the two tunnels at present leading to the West Division, as more fully set forth in the following plan for a transportation system.

GENERAL PLAN OF OPERATION UNDER UNIFIED MANAGEMENT.

For a general plan of transportation within these limits, and to meet the requirements laid down by you in my commission to "eliminate grade crossings and provide for operation of through lines between the North and South Sides of the city terminals from all divisions," the following is submitted. While there are other conditions to be considered which might not make this plan the most practicable for adoption at the present time, I submit in conjunction herewith other plans which will be subsequently considered.

The north and south surface tracks of the three divisions, at present built, including those west of the river, should be connected, and through north and south lines of cars be operated on each street. These lines to be designated the "Trunk System."

Upon the east and west tracks of the three divisions, at present built, through east and west lines of cars should be operated on each street, these lines to be designated the "Cross-Town System."

Upon the diagonal avenues radiating from the business center and paralleling the north and south branches of the Chicago River, there should be operated lines of cars between the northeast and southwest, and between the southeast and northwest sections of the city, through the business center, designated the "Avenue System."

In recognition of the fact that the business center is the objective point of a very large proportion of the city's travel, especially morning and night, whatever service that was found necessary to augment the service above set forth should be operated, as at present, from all divisions, terminating in the business center.

By using this "Business Center System," as distributing and collecting agency, the necessity of large loops is eliminated, and the limited area suitable for terminal facilities can be utilized to its fullest capacity. By the operation of such a distributing system, the through service on the north and south trunk tracks can be taken through the business center in subways under streets most suitable, without reference to any local points, and the terminal loops of the

east and west cross-town system and of the avenue system can be located with reference only to the highways over which they enter the business district.

SUBWAY PLANS.

Ultimate Objects.

In the development of the subway plans submitted herewith, there have been kept in mind the following principal objects:

First. The ultimate unification of all street railway facilities within the city limits under a single operating management.

Second. The proper location of the subway lines and the construction of a track system which will provide for the operation of cars under any of the following plans:

(A) Between the various divisions of the city through the business district.

(B) Divisional operation of the cars only; using the subway system as a loop terminal.

(C) Plans (A) and (B) in combination.

Third. To build the subway as close to the surface of the street as possible, reducing the distance from station platform to the level of the street to a minimum.

Fourth. The arrangements of a subway system to provide for the maximum efficiency with a minimum length of underground tracks.

Fifth. The disposition of all underground utilities in such a manner that they will be easily accessible without disturbing the surface of the street, and without any direct connection with the transportation subway.

SUBWAY ROUTES.

Plan No. 1.

The location of subways shown on Map No. 11, hereinafter referred to as Subway Plan No. 1, is suggested as the most feasible plan for accomplishing the foregoing objects without disturbing the existing low level improvements, which have been avoided by slightly increasing the grades of some of the tunnel entrances.

By this plan the following results would be obtained:

First. The greatest possible capacity of the limited area in the business district would be utilized for terminal facilities.

Second. All through traffic via the business center would be taken through the congested district, underground, saving time to the passenger, and relieving the congestion in this district.

Third. All subways would be on the high level without grade crossings, thus cheapening the construction and not interfering with existing low-level improvements.

Fourth. All river tunnel approaches within the business center would be closed.

Fifth. As all traffic from the north and south divisions would be underground, if Surface Plan No. 1 (Map 10) were used, grade

crossings of surface loops would be eliminated, except those incident to the operation of the local distributing system.

Plan No. 2.

Plan No. 2 is presented as the ideal solution of the questions submitted by the Council, and is shown on Map No. 5.

All of the advantages of through routes, in all directions of Plan No. 1 are retained.

This plan retains the same north and south trunk line system of tunnels as shown in Plan No. 1, except that the line on Wabash Avenue is moved over to Michigan Avenue.

In order to get the West Side lines through to Michigan Avenue, and ultimately farther east under the Lake Front Park should future extension of the park make this desirable, or if it should be thought best to connect the various passenger and freight depots of the steam railroads, a series of low level loops could be provided. These loops would extend eastward from the river at as high a level as practicable to keep underneath the north and south subways, and where they intersected the streets occupied by north and south subways, double-decked stations could be provided as shown in Plate IX of the 1902 Arnold report. In this station, as designed, all of the business would be done on the first floor below the street surface, and the lower section of the station would consist only of platforms from which passengers would board the trains. From the lower level platform to the platform of the upper subway would be provided stairs at one end, and if found advisable, elevators or escalators at the other end, thus making the ascent easy for those who desired to use them.

It will be seen that the business center of the city would, if this plan were adopted, be underlaid with a series of subway tracks intersecting each other at right angles, and at a sufficient number of points to enable passengers to travel from almost any point in the business district to almost any other point, with the least inconvenience.

The chief objections that can be made to Plan No. 2 are:

First. Its relative cost as compared with Plan No. 1.

Second. The passengers in the low level subways would be about 40 ft. below the surface of the street, thus necessitating the use of elevators between low level and high level subways at station points, a distance of about 20 ft.

Third. The engineering difficulties and risks that would be encountered in its construction.

Fourth. The fact that it would interfere, and to a large extent destroy, existing and contemplated low level improvements.

ESTIMATE OF COST.

Plan No. 1.

Plan No. 1 requires 9.42 miles of subway and tunnels, of which 5.64 miles is double track structure, and 3.78 miles is single track, providing for 15.06 miles of single track railway.

Cost of construction	\$11,433,380.00
Plus for engineering, supervision and administration.	1,143,338.00

Total for subways.....	\$12,576,718.00
Two new tunnels at Clark and Dearborn streets....	1,600,000.00
Lowering existing tunnels.....	1,500,000.00

Total	\$15,676,718.00
Say	\$16,000,000.00

Plan No. 2.

Plan No. 2 requires 7.4 miles of single track in high level subways or tunnel approaches, and 6.0 miles of single track in low level subways or tunnels.

Cost of construction.....	\$14,356,172.00
Plus for engineering, supervision and administration.	1,435,617.00

Total for subways.....	\$15,791,789.00
Three new tunnels at Clark, Dearborn and Adams sts.	2,400,000.00
Lowering existing tunnels.....	1,500,000.00

Total	\$19,691,789.00
Say	\$20,000,000.00

These figures do not include damages that might be shown to property abutting subway approaches, but as the figures are liberal they might possibly cover any such damages. The amount of these damages is a question for real estate experts, and can only be determined after exact locations for subway approaches are fixed.

ABSTRACT OF RECOMMENDATIONS AND GENERAL PLANS FOR A COMPREHENSIVE PASSENGER SUBWAY SYSTEM.

BY BION J. ARNOLD, M. W. S. E.

January, 1911.

Mr. Bion J. Arnold was appointed in 1910 as the Chief Subway Engineer of the city of Chicago, and was instructed to formulate working plans and recommendations for a comprehensive subway system for the city of Chicago.

The recommendations made are for the adoption of a plan which will form the nucleus of a comprehensive subway system for the entire city, constantly tending to enlarge the present business district, capable of gradual development and of unlimited expansion, involving no grade crossings, no grades except where necessary to pass under the river and to avoid grade crossings, and few, if any, intersecting switching points, and also to begin the construction of such a system with a reasonable investment at first, which invest-

ment need not now exceed the amount available by the city for subway construction.

Plan No. 1 (Map VI), is for a high speed, comprehensive system, designed to ultimately cover the entire city, in which could be operated high speed and local trains, independent of any of the present traction companies. This system could be built by the city or by private capital, without the use of any moneys from the present surface line companies, or by utilizing this money if the city decide to do so. Upon the tracks of this subway could at first be run the present surface line cars, later the trains of the present elevated roads, and finally, when extended, the trains of a high speed comprehensive subway system covering the entire city. Thus it would be possible to promptly relieve the present surface line congestion at moderate cost by constructing only a portion of the system at first, and later eliminating the entire present elevated loop structure, if conditions should come about so that this could be accomplished, and at the same time have the nucleus of a high speed subway system, which could be extended from time to time, as conditions warranted, until it covered the entire city, approximately as shown on Map VII. This plan, for convenience to the general public and from an investment and operating viewpoint, would be the most economical plan to adopt, and in the report is shown in its progressive steps, or stages of construction, on Maps I, II, III, IV, V, VI, VII, and VIII.

Plan No. 2, shown on Map VIII, is for a system designed to be used exclusively by the surface line cars for the relief of present congestion in the business district, utilizing the existing tunnels under the river, and so located that it would not interfere with the ultimate construction of the high speed subway of Plan No. 1. Under this plan the city could allow the surface line companies to construct a subway system, suitable for surface cars, with their own money, or call upon the present surface line companies for the money defined in the ordinances, and construct it jointly with them, or not, as it saw fit. Since the system is located upon streets which would not be necessary in the construction of the system outlined in Plan No. 1, the city's interests would not be jeopardized for the ultimate construction of a future independent high speed subway. Should it be decided to construct at present under Plan No. 1, and the requirements of the future make it necessary to have additional terminal subways in the present business district, Plan No. 2 could be utilized.

Fundamentally, no subway plan should be adopted involving any system of loops, or other methods of construction, which will prevent the building of a high speed subway system ultimately covering the entire city, through which high speed trains could be run, for no extensive subway system can be justified from an investment viewpoint, unless it is so designed that ultimately high speed trains each having a capacity of not less than ten of the present elevated

cars could operate through it at times of maximum traffic, as it is only by this method that the cost of operation per car mile of such a system can be brought low enough to justify the heavy investment necessary for long distance subways, and take care of the high fixed charges necessitated in their construction. This does not mean that, aside from financial reasons, it is not advisable to construct at once enough subway in the business district to relieve the present congestion of surface and elevated cars. But it does mean that the ultimate plan to be kept in mind in analyzing the transportation problem of the city of Chicago should be one that will lead toward securing a transportation system that, no matter how owned, will eventually gather the passengers by means of surface line cars and deliver them to high speed subways or elevated trains which, in turn, will bring them to and through the business district, to whatever extent it may be expanded, in economically and safely operated heavy, high speed trains, stopping infrequently, in order that high average speed may be made, with the intermediate points between these stops served by the present surface line cars or local elevated or subway cars. In such a system the elevated lines would serve the same purpose as subways for such territory as they occupy, if operated into and through the present and future congested business district in subways.

The principles upon which such a subway system should be constructed are as follows:

First. Through operation from the southern termini to the northern termini, wherever they may be located, and *vice versa*, upon as straight tracks as practicable, on one or more of the following streets: Michigan Avenue, Wabash Avenue, State Street, Clark Street, Fifth Avenue, Halsted Street, Western Avenue, etc., as the future may demand.

Second. Similar east and west subways, with the grades separated where they cross the north and south subways, located, to start with, say, on Madison Street, and eventually upon such other east and west streets, north and south of Madison Street, as future conditions may demand, utilizing, however, at once certain of these streets in the present business district for loop terminals for the present West Side surface and elevated cars, but so arranged that the subways so used may finally be used for future subway cars.

Third. These north and south and east and west subways eventually to be supplemented by diagonal subways upon Milwaukee Avenue, Blue Island Avenue, Archer Avenue, and such other diagonal streets, as the future may determine best to locate subways.

Since the city extends in three directions only, it is necessary to return to the West Side some of the cars coming from that side, by reversing their direction, either by means of stub end or loop terminals. This is accomplished in the plan under consideration by loop terminals in preference to stub end terminals, for by the loop method continuous operation is permitted with the corresponding

increased capacity and speed, and the elimination of danger in operation.

The east and west subways (with the exception of the one on Randolph Street, which must run at high level east of the south branch of the river in order to allow the north and south subways to pass under the river at grades not exceeding those of the west side subways), after once having descended to come under the river, should remain down and pass under the north and south subways in the present business district, although west of the south branch of the river, the east and west subways could be constructed as high level subways, but dipping to allow the Halsted Street and Western Avenue subways, or such other north and south subways as may be constructed upon the west side prior to the construction of the east and west subways, to pass over them. In case the east and west subways on the west side of the river are constructed first, the north and south subways should dip at intersecting points.

SUMMARY.

The advantages of the complete scheme embraced by Plan No. 1 are set forth in a summary, as follows:

(a) A comprehensive system starting with a nucleus involving a small investment but capable of gradual expansion until the system covers the entire city.

(b) No grade crossings.

(c) High speed straight line operation, with few switches or curves.

(d) Least practicable first cost.

(e) Great flexibility, and always tending to enlarge the business district in three directions.

(f) Ease of access to passengers, owing to the shallowness of the high level subways, which allows the platforms of the low level subways to be within 28 ft. of the surface of the streets.

The cost is estimated by steps aggregating, for the complete Plan No. 1, \$48,950,000 for 46.2 miles single track, and for Plan No. 2, \$9,250,000 for 9.8 miles single track.

The cost per mile of single track, including stations, varies from \$726,710 to \$1,421,100, averaging \$1,060,000 per mile of single track.

Either plan is so laid out that connections can be made at suitable points to provide for through routing of cars between the three divisions of the city, if it is thought desirable.

DISCUSSION

President Reichmann: In order to allow more time for discussion of the subject this evening, our Past President, Mr. O. P. Chamberlain, has consented to present a synopsis of the abstracts which have been printed and sent out in advance.

O. P. Chamberlain, M. W. S. E.: Our Secretary tele-

phoned me about a week ago that this synopsis of certain papers in regard to the Chicago subways had been prepared and that I was requested to present a synopsis of the synopsis. I inquired why it was that I had been selected for this, never having been connected with the Chicago subways. He replied that that was the reason, that I was the only Past President of the Society who had not in some way been mixed up in the Chicago subway proposition.

At the time of the World's Fair in 1893 I visited Chicago, my home then being in the East, and to me as a young man the subways under the river were quite novel and wonderful. We had nothing of the kind in the East at that time. Since then an effort has been made in Chicago to adopt some comprehensive plan of subways, or at least to get started on subways to relieve congestion, particularly in the downtown district. The eastern cities, which at that time had nothing in the way of a subway (not even New York, Boston, or Philadelphia), have since completed elaborate systems of subways. On returning from New York City about three years ago, one of my friends who formerly lived in the East asked me how the city looked. I told him I did not have much time, and what time was not spent in attending to business was spent in the tubes, consequently I saw New York from the bottom and did not know how it looked on the surface.

Quite a comprehensive system of subways has been developed in New York City; the same applies to Boston. Even in Philadelphia, with its proverbial slowness, some beautiful subways have been built.

In the meantime Chicago has struggled with its problem on paper and we have before us a synopsis of a number of the papers and reports which have been presented from time to time, ranging in date from 1902 to the present time.

Considering the estimates, some of which call simply for the estimated cost for single track, those for the tunnel-cost vary in these different papers from \$1,251,000 to \$3,375,000 per mile, depending, of course, upon the character of the tunnels which were recommended. There are some things mentioned which I have not read or at least only briefly touched upon, one of which is the necessity of finding means to take care of public utility wires, conduits, and so on, together with the sewage system, if we occupy our downtown streets with subways. Anyone who has business requiring underground work—for instance anyone connected with the Commonwealth Edison Company—is familiar with conditions downtown. When these streets are opened up, especially in the immediate vicinity of the City Hall,—take Washington, Randolph, Clark, Dearborn, any of those streets,—I suppose one could not open up a square yard anywhere without striking something which has been put in there either by the City or one of the public service companies. This is one part of the problem which I think has not been thoroughly worked out. Of course, it is not yet time to work it

out. Mr. Ericson, in one of his earlier schemes, refers to the possibility of carrying these details between the curb line and the building line under the sidewalk. I doubt very much whether in the congested district this can be done. It seems to me the most feasible plan is that presented by Mr. Arnold, namely, a high-level subway, or, whether it is high level or low level, putting these public utility necessities below the tracks in the subway.

President Reichmann: I believe Mr. Bartlett has prepared a written discussion.

H. E. Bartlett: As Mr. Chamberlain says, the question of subways has been studied since 1902, and a great many schemes have been presented. I will attempt to add one more, because I have given considerable attention to the question. As the hour is getting late I will read simply what I have here. It is an article written some two and a half years ago and in a few places things have changed since that time.

The need of a system of subways to relieve the present intolerable traffic congestion in the business district of Chicago has been so thoroughly presented by others that it will not again be dwelt upon. The system I am about to describe will render possible the removal of all surface cars from the streets of the "subway district" described later; will permit the greatest freedom of movement of surface cars, and will for a great many years, if not permanently, place the elevated railroads in a position to handle their traffic in first-class manner. In addition to the above, this plan permits the removal of three sides of the Union Loop, and ultimately the entire structure, by placing the Fifth Avenue portion thereof in subway. The business district may be expanded indefinitely and the construction of high speed subways outside of the "subway district" will ultimately solve perfectly the transportation problem in this city.

The first step is the defining of a "subway district," within which all trains or cars will run as "locals," and beyond which express or local service may be used as desired. These limits correspond closely to what are now the express service limits of the elevated companies, viz., Chicago Avenue on the north, Desplaines Street on the west, and Twelfth Street on the south, and for nearly all initial subways the approaches to the subway bores would be immediately within these streets. Thus the movements of cars into the bores and their distribution would take place exactly as on the surface, thus avoiding the construction of expensive connections in subway. When the time shall come that it is desired to bring the cars to the subway district by means of other subways, then the track on these limiting streets named above, would be placed on the level of the connecting subways, and the street roofed over so that all transfers of cars from one loop to another, or other complicated movements might still be made as if the tracks were on the surface. Probably the time will come when it will be deemed desirable

to install high speed tracks for the present surface car lines with operation as to express and local service about as with the present elevated car lines. An example might be made of Madison Street as one of the first to need this kind of attention after the primary system of subways is constructed. To this limiting street (Desplaines Street) could be brought cars in subway over two, three or four tracks, as may be desired. In this street they may be shifted to any desired bore and return over any other desired route, exactly as if the movements were on the surface.

By referring to the accompanying map, Plate XII, the general features of the system may be seen. The portion on Fifth Avenue within the subway district may eventually be placed in subway, thus entirely eliminating the structure of the elevated railroads in the business district.

From published reports it appears that a merger of the elevated roads of the city is a matter of but a short time, hence the following description of the operation will be on the assumption that the merger has taken place. Should it be desired to retain the separate operation, it would be necessary to construct loops around blocks in the vicinity of Chicago Avenue and Franklin Street, and at Twelfth and State Streets.

By reference to Plate XII, the operation of the elevated lines may be described as follows: Leaving the structure of the South Side Elevated line near Sixteenth Street, a train proceeds by the incline into a subway bore on the east side of State Street; thence due north through State Street to Chicago Avenue; thence west to the elevated structure of the Northwestern Elevated Railroad near Franklin Street and Chicago Avenue, where it ascends to a connection with the Northwestern Elevated at the Oak Street station, while other trains move in the opposite direction through a parallel bore.

In a similar manner the trains of the Metropolitan Elevated road would leave that structure just east of the Center Avenue station, and go into a subway at Halsted and Harrison Streets; thence east in Harrison to State Street; north in State Street to Randolph; west on Randolph to Morgan Street; thence to the elevated structure of the Chicago & Oak Park Elevated line, or else return to its own line via the elevated structure on Morgan Street, this being that portion of the Union Loop now located on Wabash Avenue. In a similar manner the trains from the Oak Park Elevated line will reach the structure of the Metropolitan Elevated line or back to its own tracks as above described. Trains on all roads making the above movements would be marked SUBWAY.

Similarly, trains from the elevated lines of the North and South Sides would pass over the present Fifth Avenue leg of the Union Loop extended south to Polk Street; thence east to a connection with the present structure of the South Side line near Polk Street as shown in heavy black lines. These extensions may be made

by utilizing the legs of the present loop structure on Lake Street and Van Buren Street.

In the same way, trains from the West Side lines would inter-

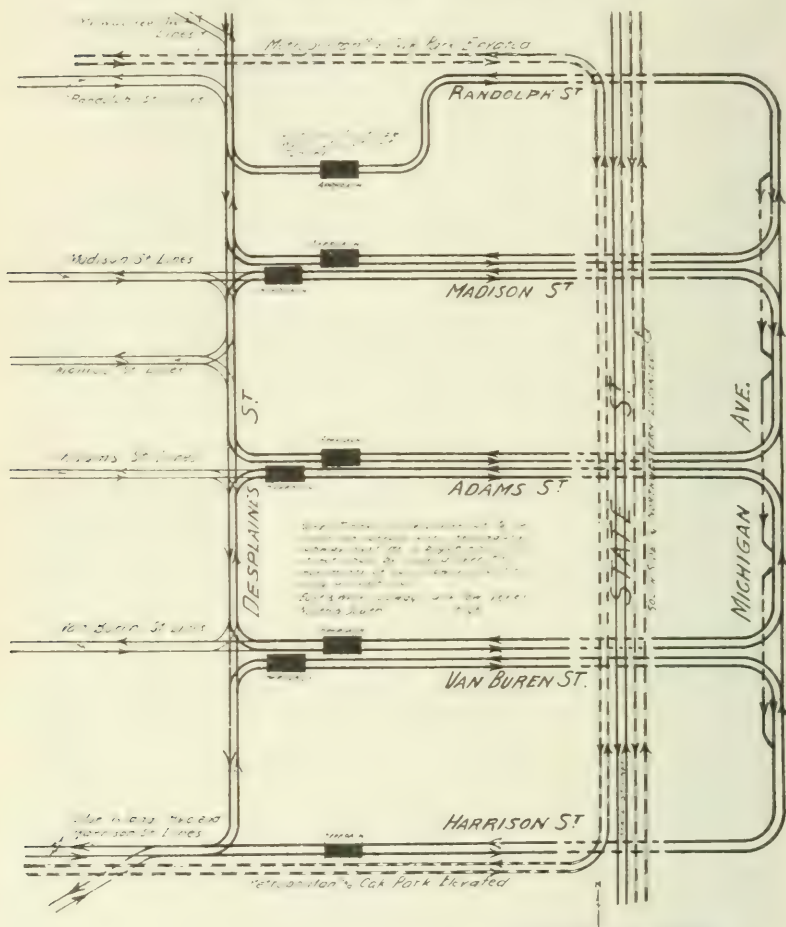


DIAGRAM SHOWING
SUGGESTED METHOD OF OPERATION OF
PROPOSED SUBWAY SYSTEM
CHICAGO

NOT TO SCALE

H. F. BARTLETT, CIVIL ENGINEER CHICAGO APRIL 8, 1911

Fig. 3

change over the present lines in conjunction with the Fifth Avenue leg of the Union Loop. Trains so operating would be designated as FIFTH AVENUE. Thus two avenues are opened for the pas-

sage of the elevated trains, and it can be readily seen that they furnish facilities equivalent to four tracks on each of the structures of the elevated lines, which is evidently their maximum capacity. In addition, the use of the present stub terminals would not be interfered with.

SURFACE CAR LINES IN SUBWAY

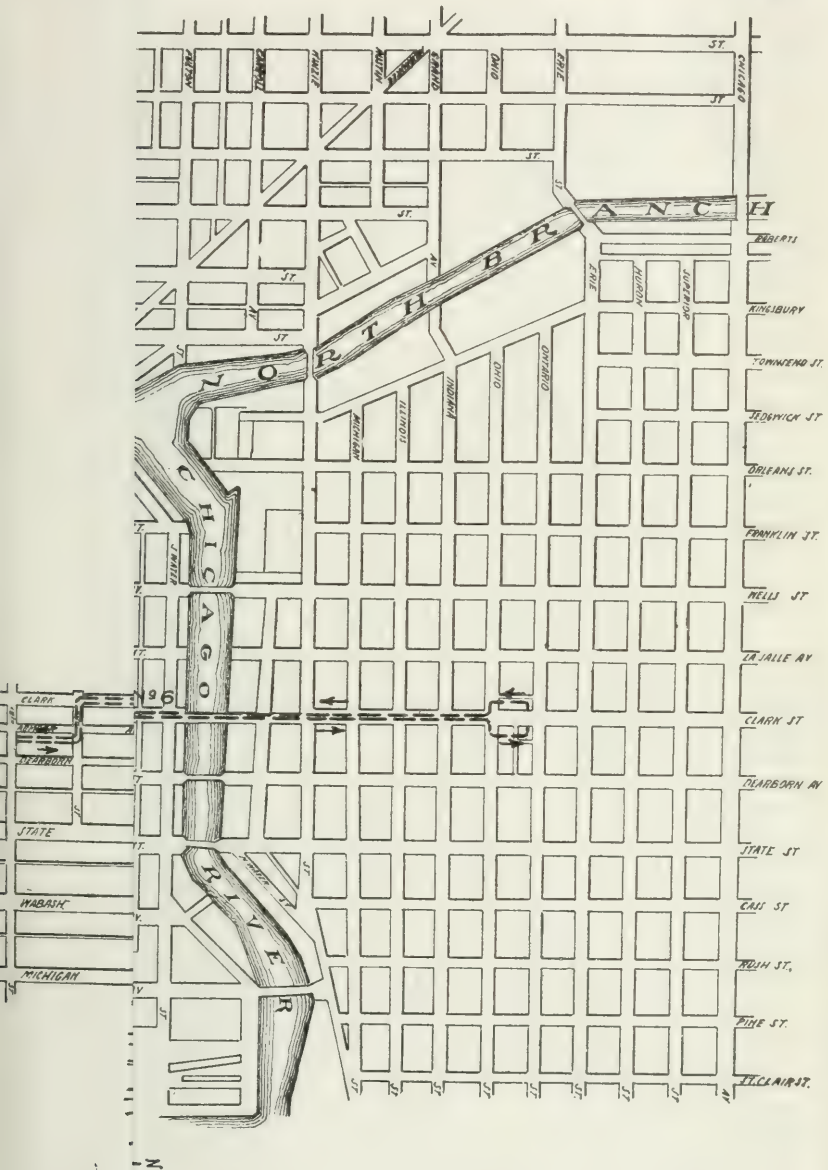
From an inspection of the map it will be seen that the system contemplates the construction of a double-track north and south subway line through State Street by which cars could be through-routed from the North to the South Sides. Four tracks on Wabash Avenue furnish a means for a through route to the West Side via Randolph Street, or a loop as at present. Four tracks on Clark Street furnish through-routing from the North and South Sides, or a loop near the City Hall, as may be desired.

The construction of four-track subways on Madison, Adams and Van Buren Streets, together with two tracks for surface cars on Harrison and Randolph Streets, furnishes a system of loops for the West Side lines that will provide an effective means of interchange of cars. It is believed that the principle of the occupation of the full width of each street is correct, in that it gives cheaper proportional first cost and also utilizes the full capacity of each street, leaving the remaining streets (*i. e.*, Lake, Washington, Monroe and Jackson) for the construction of a similar system, as the demands of the city's growth require.

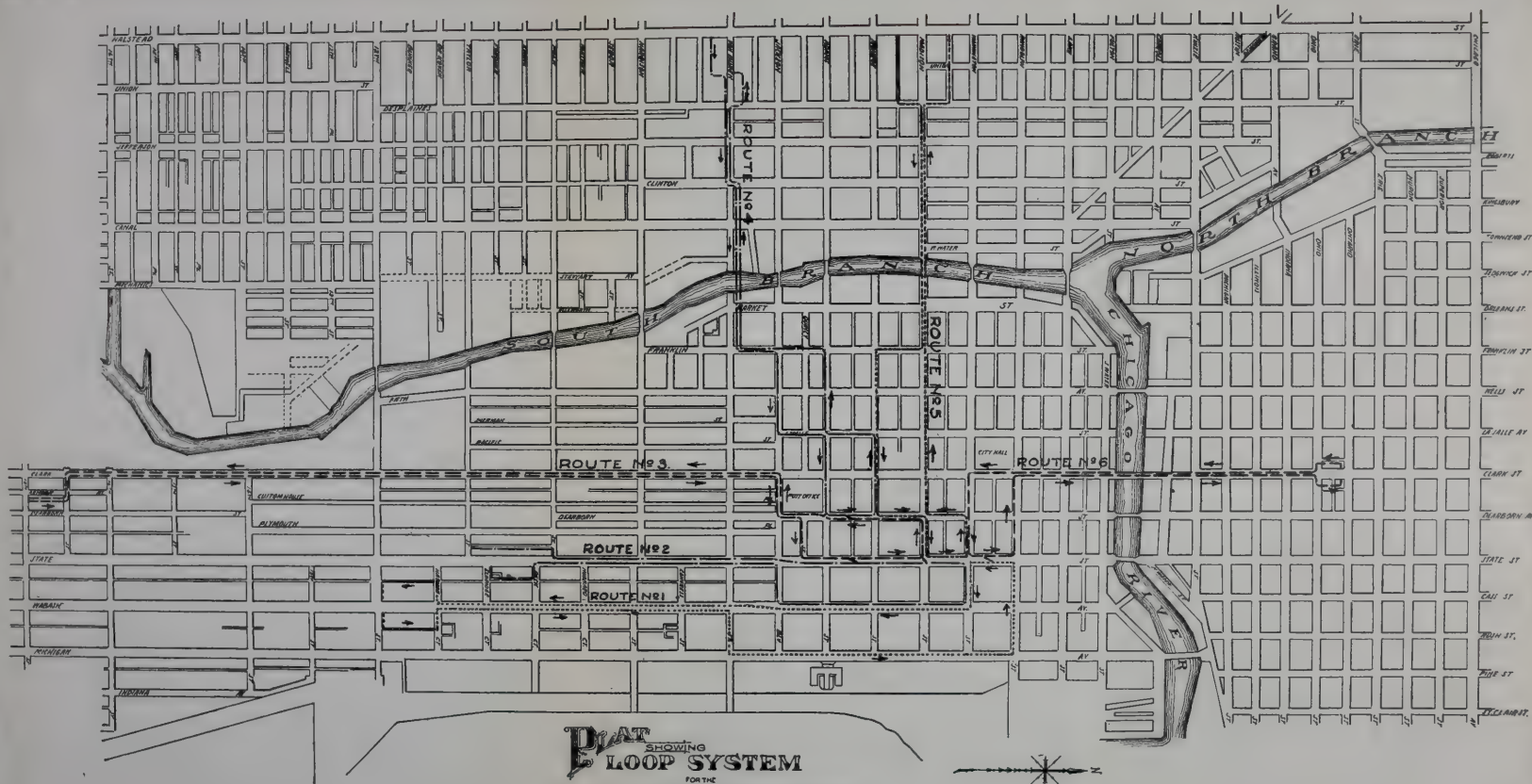
As before stated, these loops terminate on the surface in Desplaines Street. The operation of the cars on a single loop will suffice to explain the principle. For instance, a Van Buren Street car approaching Desplaines Street from the west will pass into the subway bore on Van Buren Street; thence east to Michigan; thence north to Adams; west on Adams to Desplaines; thence to Van Buren and on Van Buren Street to its destination. The car immediately following the one above described will pass around this loop in the opposite direction, making the crossing on Desplaines Street on the surface of the ground until such time as the subways are extended beyond Desplaines. The Adams Street cars would use the same loop in the same manner. In like manner the Harrison Street, Blue Island Avenue, Adams Street, Madison Street, Milwaukee Avenue and other lines entering from the West would be taken care of, and a passenger could take an outbound car on either leg of the loop without the necessity of riding around the portion on Michigan Avenue. This is a very important item, as it largely reduces the dead haul, if such there may be. At the time the initial portion of the system is constructed, temporary loops of short radii could be constructed in Michigan Avenue for the subway bores on Harrison and Randolph Streets.

By referring to the map it will be seen that any car entering the subway on Wabash Avenue may go west by way of Michigan

714A



414A



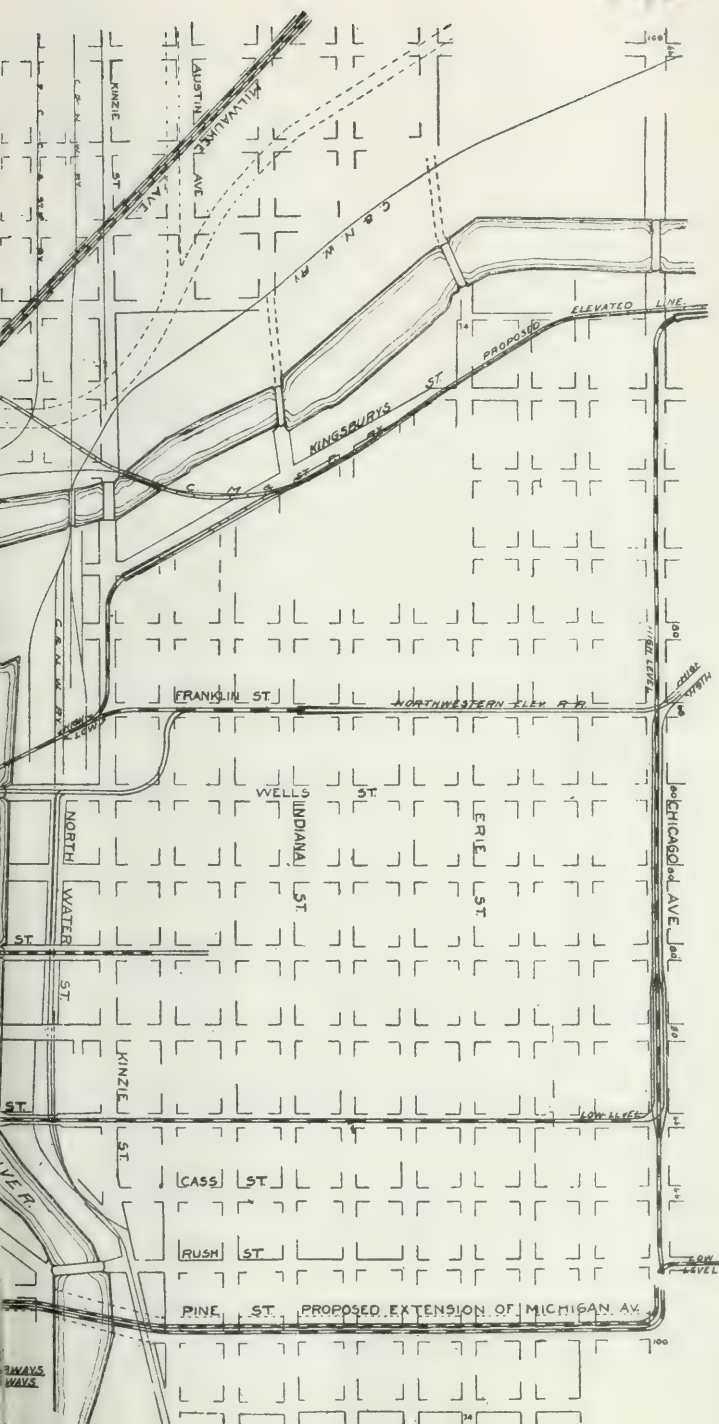
**PLAN SHOWING
LOOP SYSTEM**

FOR THE
COMMITTEE ON LOCAL TRANSPORTATION

WILTON J. FOREMAN
CHAIRMAN

G. W. Jackson
Consulting Engineer

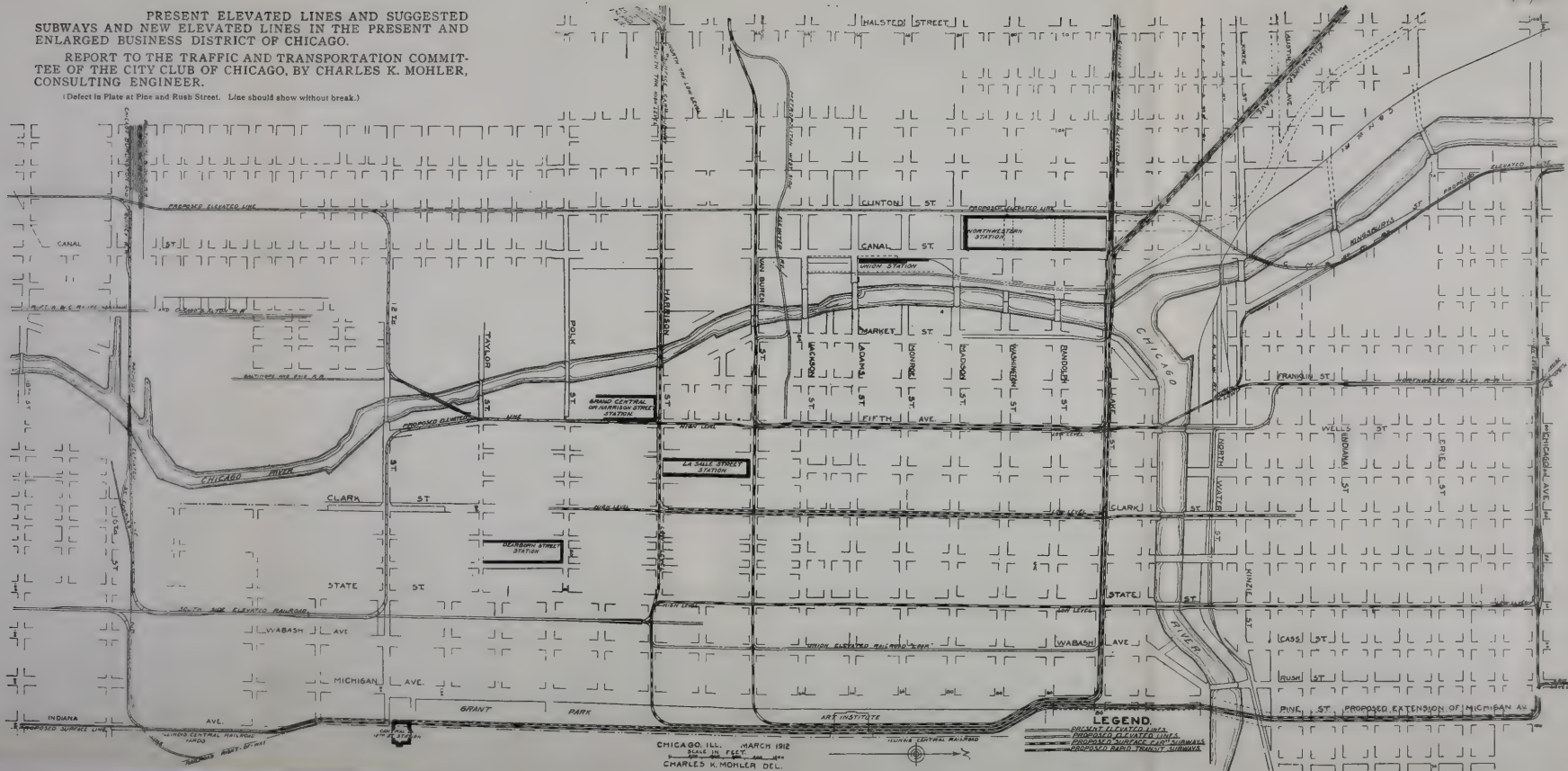
WESTERN SOCIETY OF ENGINEERS
 Vol. XVIII. No. 9, Nov., 1913.
Mohler's City Club Plan.
 Plate II.



PRESENT ELEVATED LINES AND SUGGESTED
SUBWAYS AND NEW ELEVATED LINES IN THE PRESENT AND
ENLARGED BUSINESS DISTRICT OF CHICAGO.

REPORT TO THE TRAFFIC AND TRANSPORTATION COMMITTEE
OF THE CITY CLUB OF CHICAGO, BY CHARLES K. MOHLER,
CONSULTING ENGINEER.

(Defect in Plate at Pine and Rush Street. Line should show without break.)



914C.

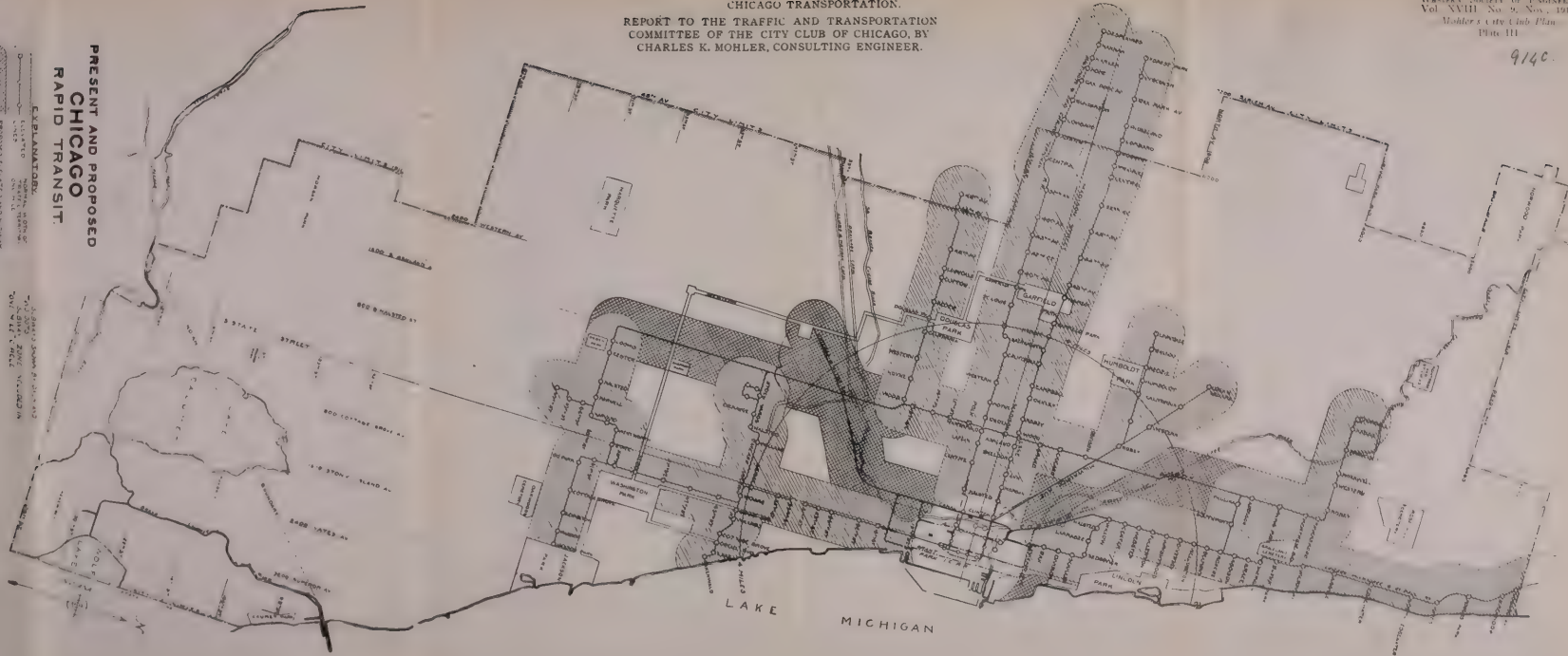


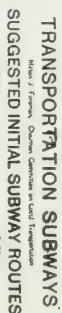
9140

CHICAGO TRANSPORTATION.
REPORT TO THE TRAFFIC AND TRANSPORTATION
COMMITTEE OF THE CITY CLUB OF CHICAGO, BY
CHARLES K. MOHLER, CONSULTING ENGINEER.

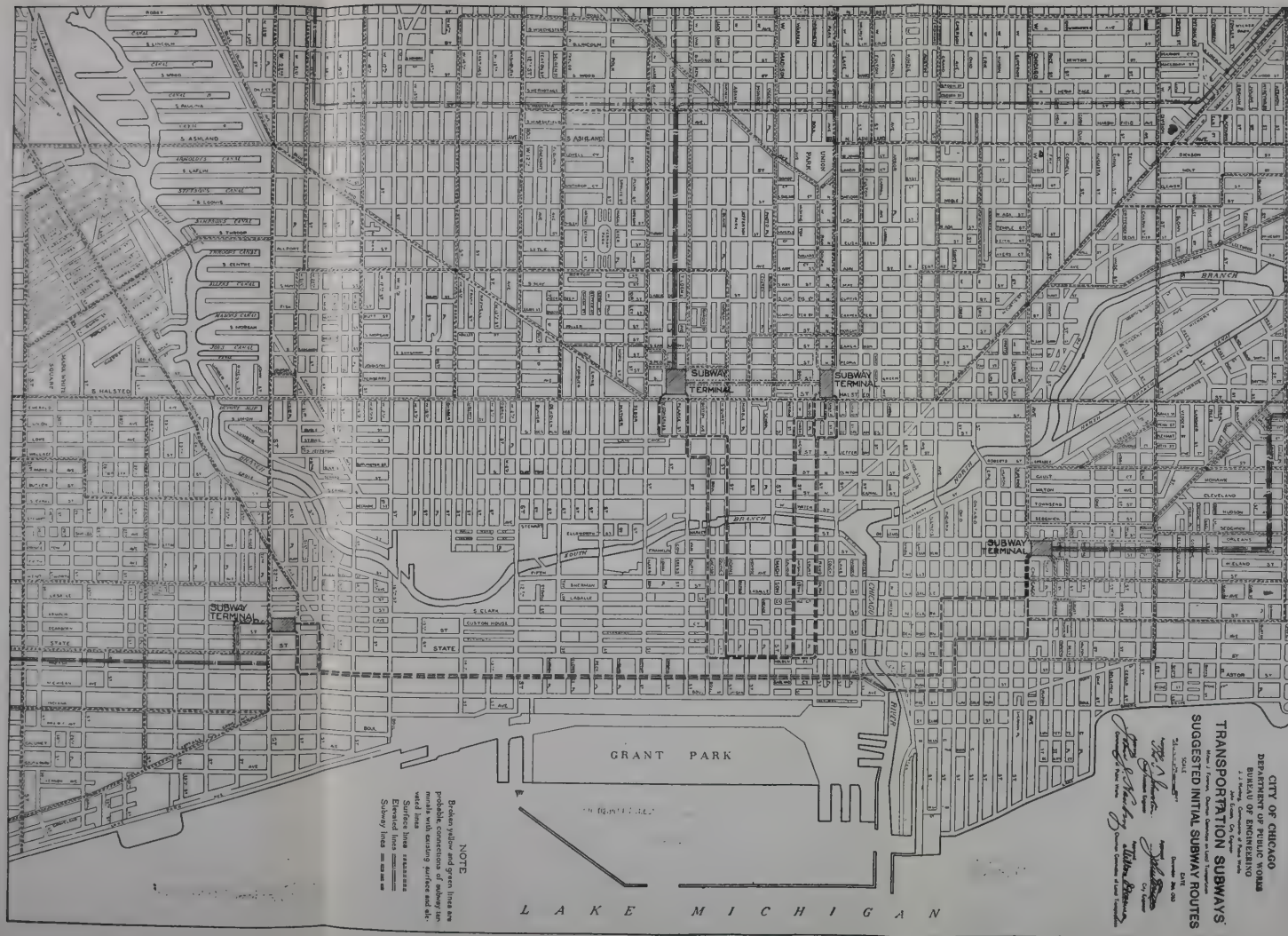
PRESENT AND PROPOSED
CHICAGO
RAPID TRANSIT.

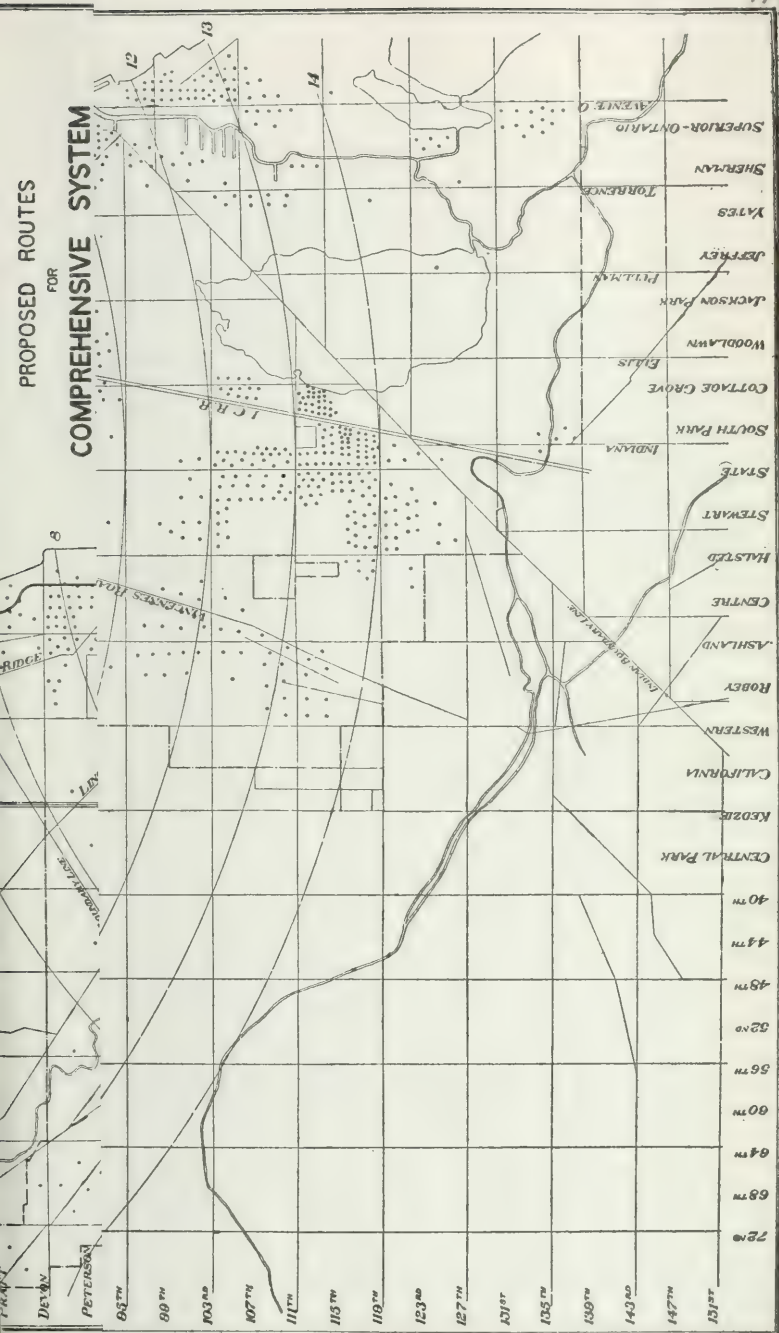
EXPLANATORY.
ILLUSTRATION, NORTH, SOUTH, EAST, WEST, AND DIAGONAL LINES.
PROPOSED RAPID TRANSIT LINES AND STATIONS.
EXISTING RAPID TRANSIT LINES AND STATIONS.





9142



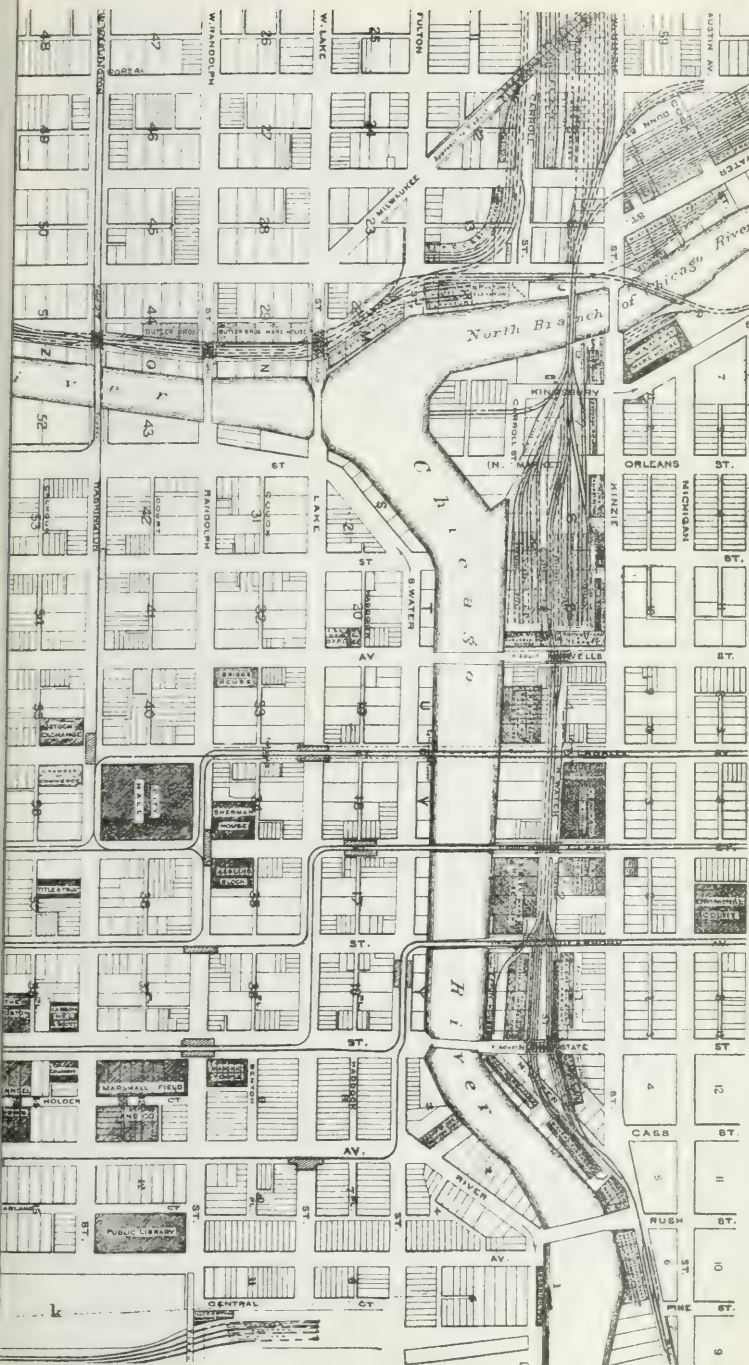


HARBOR & SUBWAY COMMISSION
1912
PROPOSED ROUTES THUS

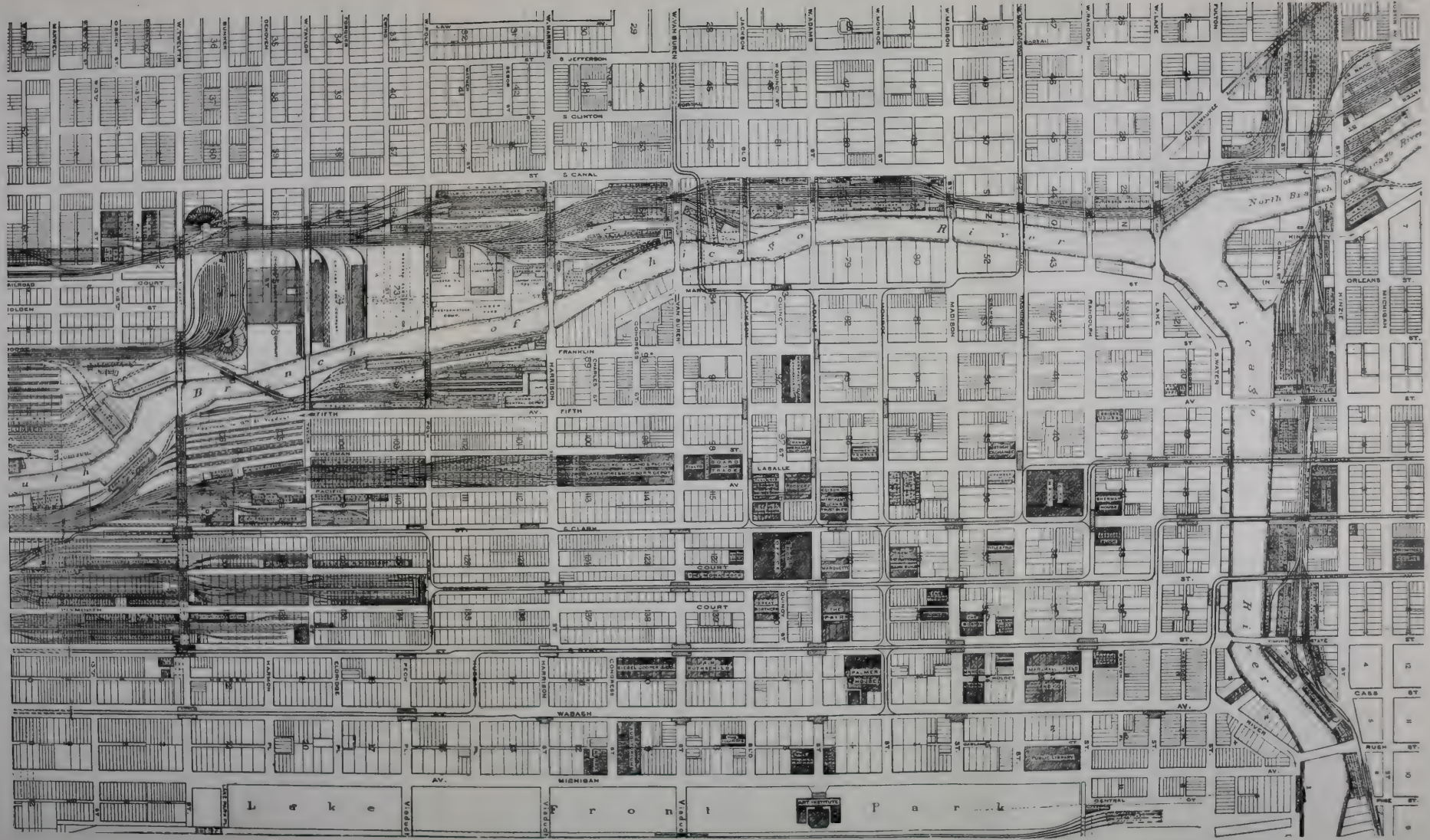
POPULATION TAKEN FROM U.S. CENSUS OF 1900
EACH DOT REPRESENTS 200 PEOPLE

HARBOR & SUBWAY COMMISSION
1912

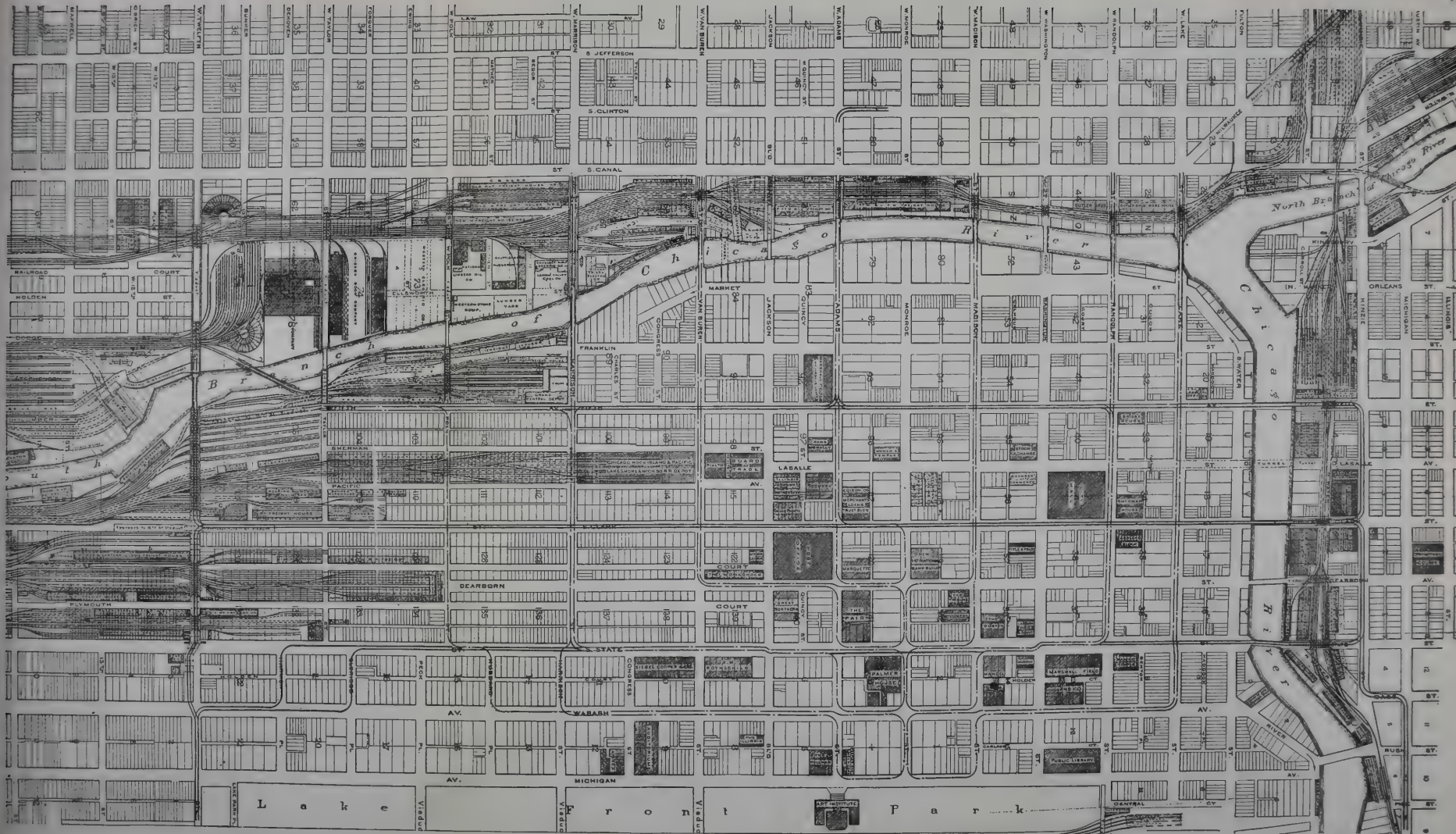
PROPOSED ROUTES MAY BE



916 F.



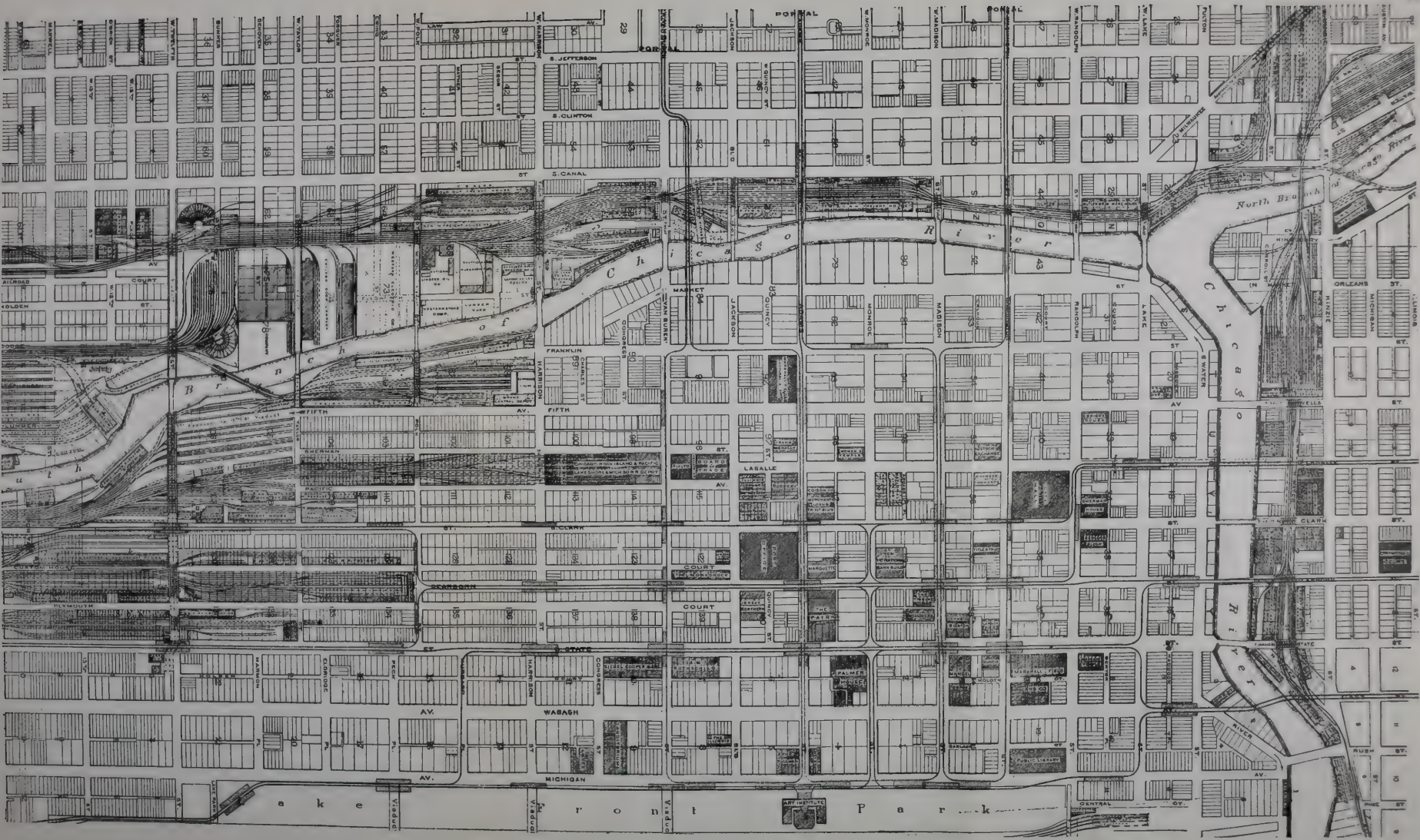


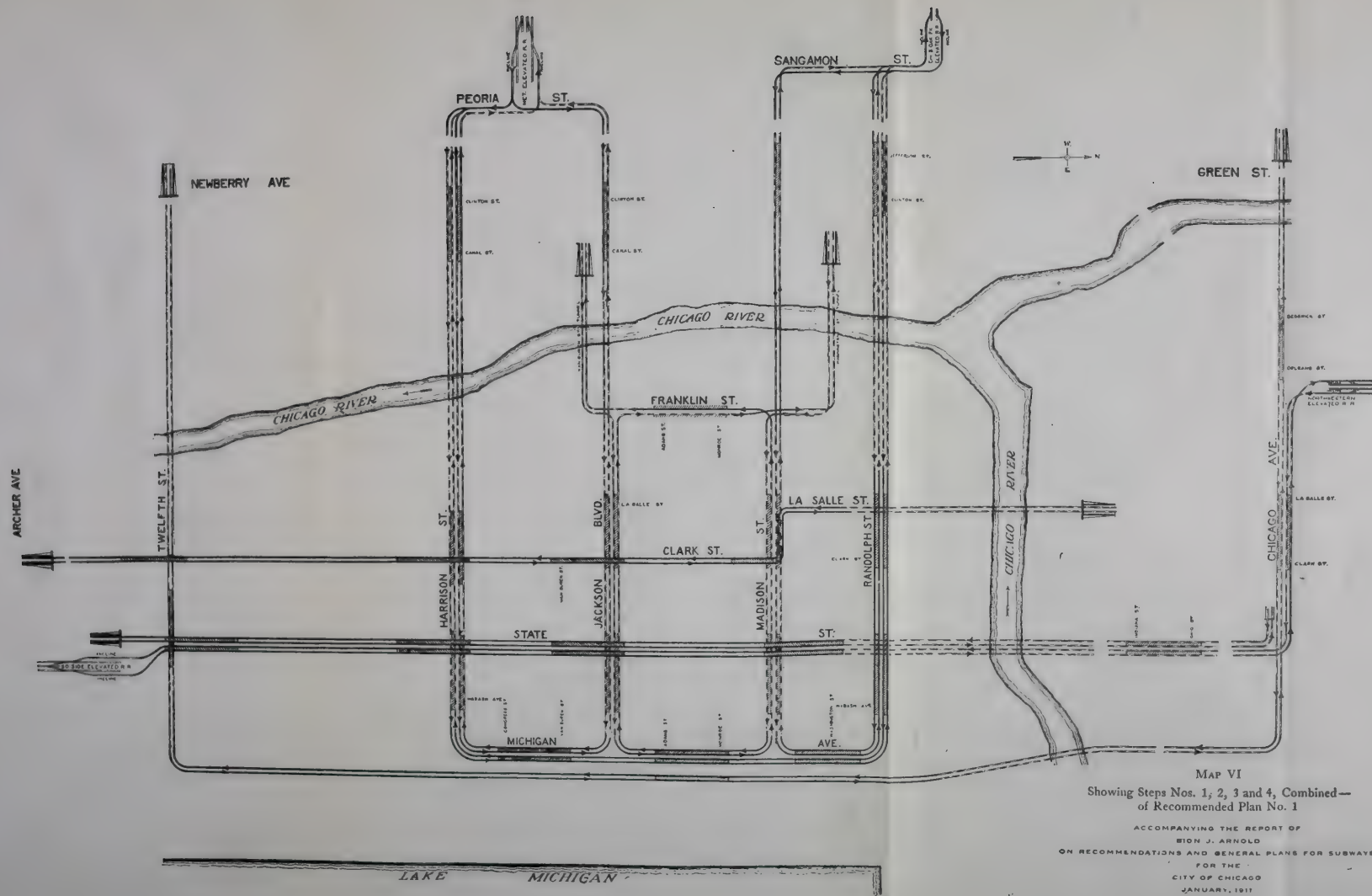


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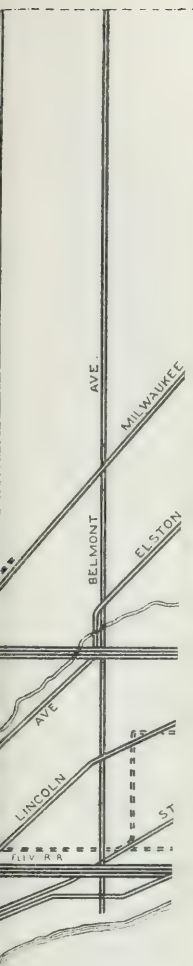
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MAP VI
Showing Steps Nos. 1, 2, 3 and 4, Combined—
of Recommended Plan No. 1

ACCOMPANYING THE REPORT OF
BION J. ARNOLD
ON RECOMMENDATIONS AND GENERAL PLANS FOR SUBWAYS
FOR THE
CITY OF CHICAGO
JANUARY, 1911

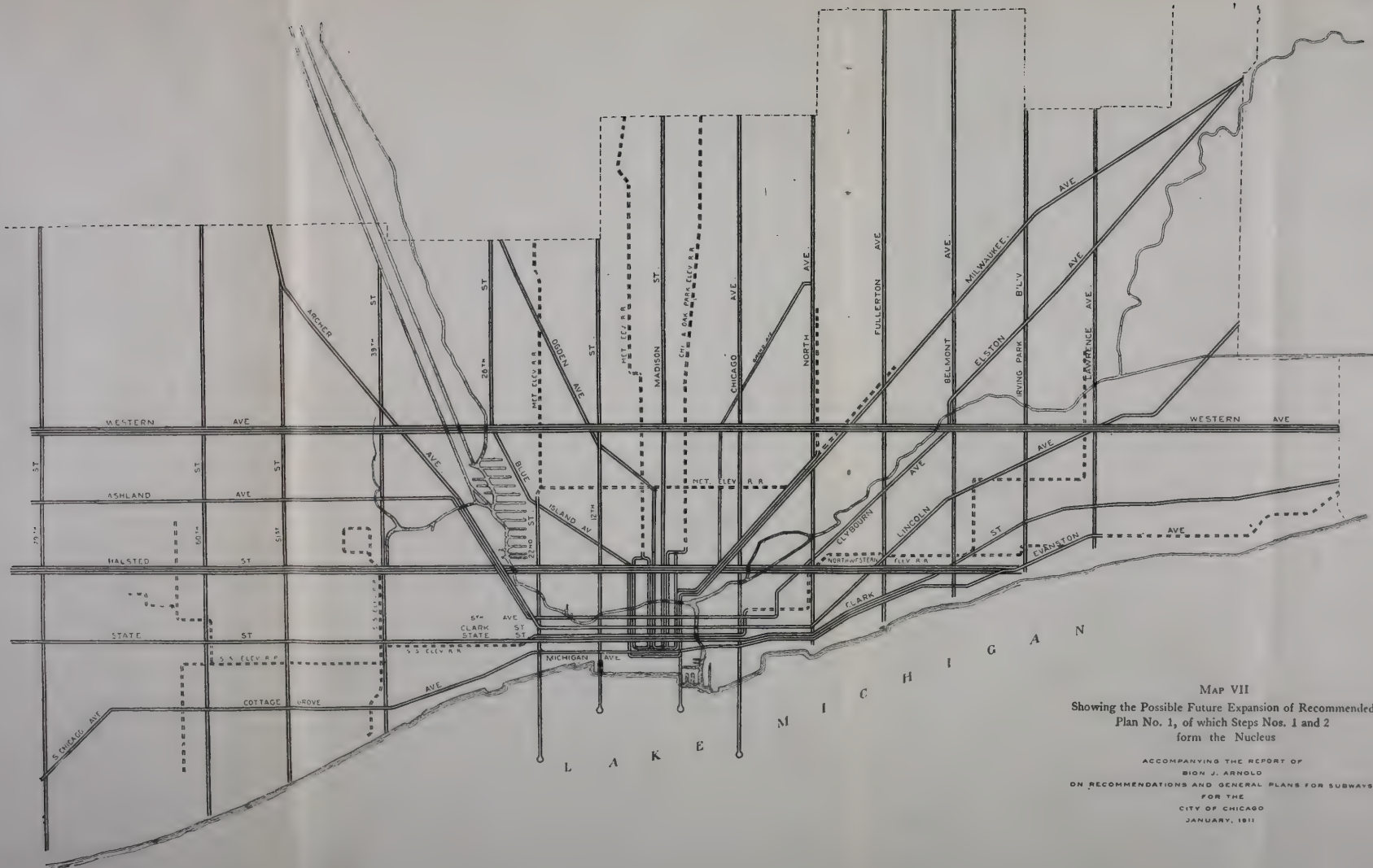


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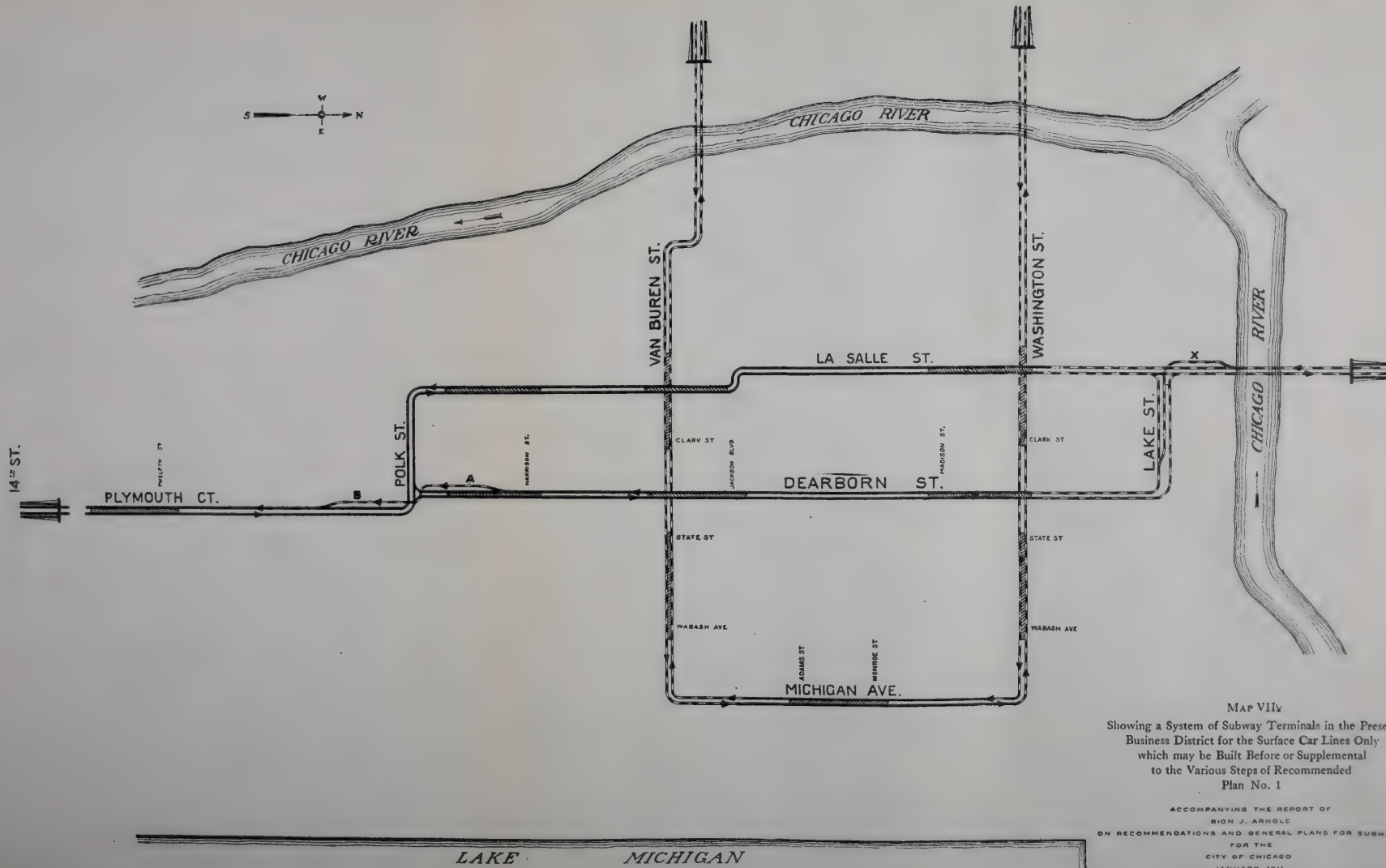
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MAP VII
Showing the Possible Future Expansion of Recommended
Plan No. 1, of which Steps Nos. 1 and 2
form the Nucleus

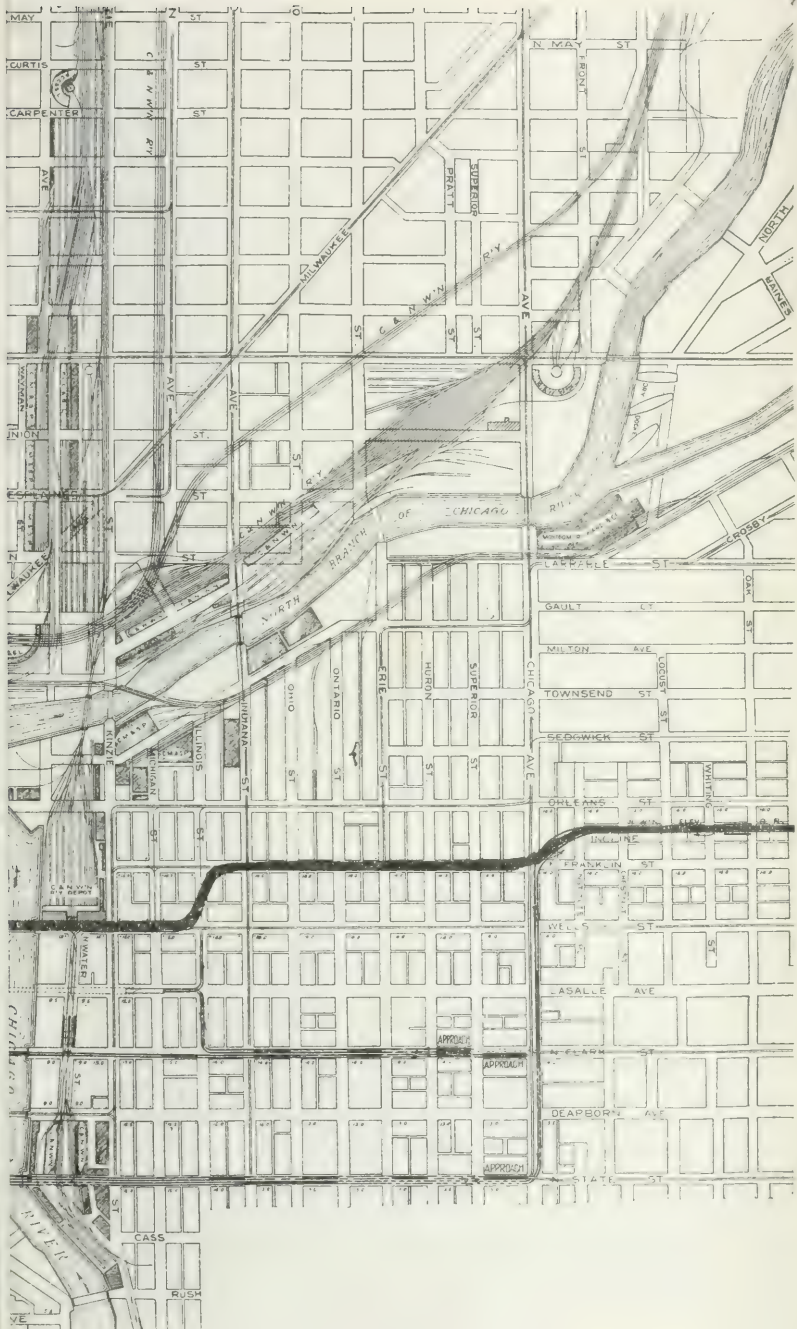
ACCOMPANYING THE REPORT OF
BION J. ARNOLD
ON RECOMMENDATIONS AND GENERAL PLANS FOR SUBWAYS
FOR THE
CITY OF CHICAGO
JANUARY, 1911

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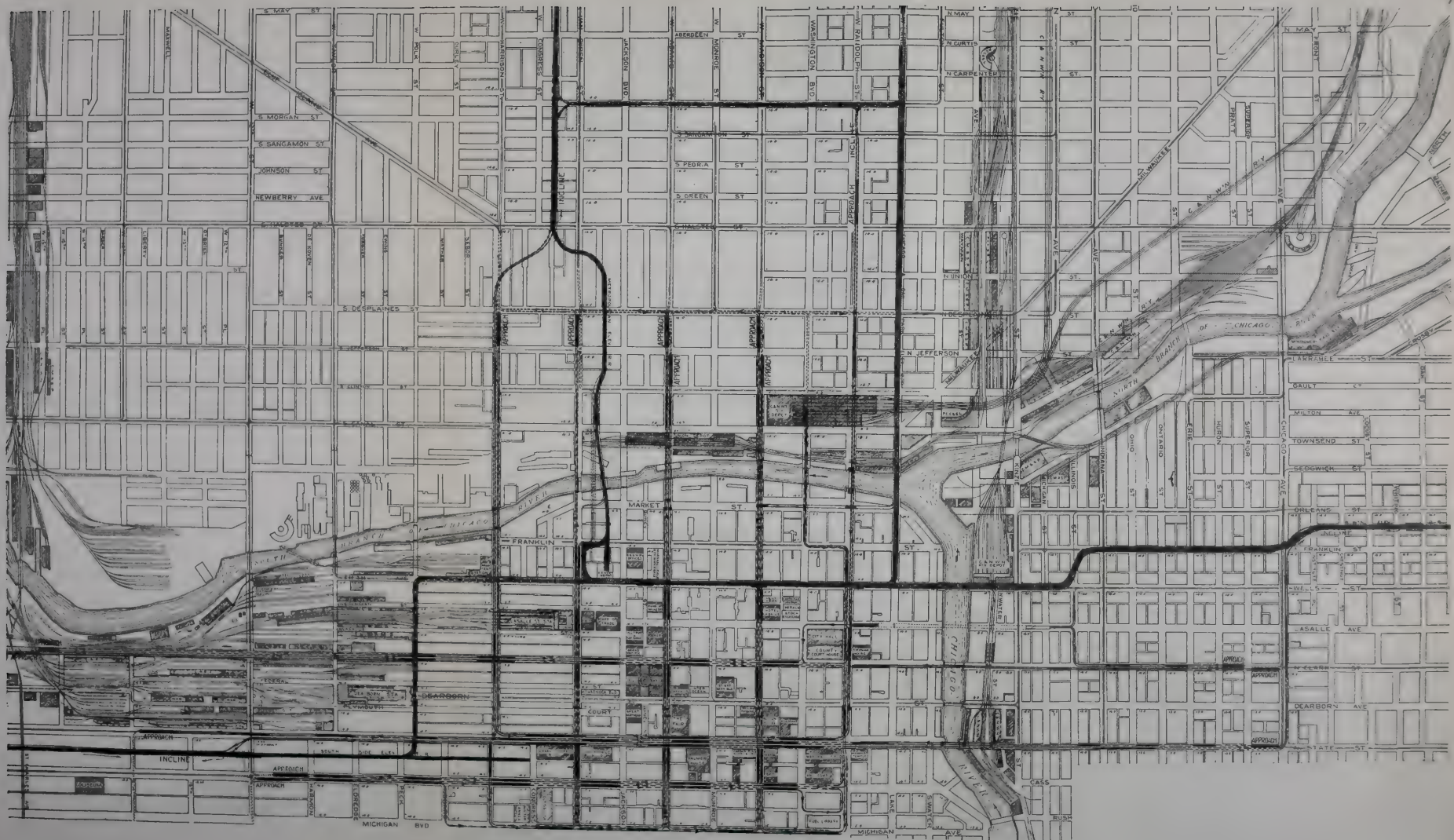


MAP VIII
Showing a System of Subway Terminals in the Present
Business District for the Surface Car Lines Only
which may be Built Before or Supplemental
to the Various Steps of Recommended
Plan No. 1

ACCOMPANYING THE REPORT OF
BION J. ARNOLD
ON RECOMMENDATIONS AND GENERAL PLANS FOR SUBWAYS
FOR THE
CITY OF CHICAGO
JANUARY, 1911



9106



Avenue on any one of the loops, and that by inexpensive construction any car from the West Side may be routed through Wabash Avenue. Any car from the West Side may reach any portion of any loop via Michigan Avenue, thus giving practically universal connections and still not require more than three tracks on that street.

The system outlined above and shown on the map may be constructed at an estimated cost of \$35,000,000 as against about \$55,000,000 for Mr. Arnold's plan. When so constructed it will care for twice as many cars as are now operated through the business district, and by the construction of a similar system of loops on the remaining streets, as Lake, Monroe, Washington and Jackson, a system may be built that will care for about three and one-half or four times the present traffic in the business district without restoring any portion of the cars to tracks on the surface of the ground, unless desired. The initial portion (being that part in State Street, Harrison Street, Randolph Street and Chicago Avenue, including connections to elevated lines) may be built for \$12,000,000, and this will cure all the ills of the elevated lines and give a large measure of relief to the surface lines.

It is perhaps unnecessary to state that there will be no grade crossings in subway and that no grades will be used except such as the best practice may dictate, viz., not to exceed 3% for elevated lines and perhaps 5% for surface cars. It will be noted that proper underground connections are easily made between the various elevated railroads and surface-car platforms on State Street, and that to reach an elevated station from any point within the present loop will require no longer a walk than about two and one-half blocks. All the large stores on State Street are easily accessible, and the number of curves is reduced to the minimum. Minor details are not herein discussed, as they are largely a matter of standard practice.

It may be mentioned that the above scheme is not obligatory, it being quite as easy to run all the cars around the loops in the same direction, should it be desirable. Also, that by use of the DuPont, or similar, car (this being one in which the body of the car is swung between the trucks and near the top of the rail, thus very materially reducing the depth of bore required to accommodate it), that the above estimate of cost may be reduced by about 40%. This style of car could readily be used to replace the present equipment for surface lines passing through subways, the cars now used being placed on lines not so used.

President Reichmann: We have the pleasure of having with us this evening Alderman Block. We would like to hear from him.

Alderman Eugene Block (Chairman, City Council Committee on Local Transportation): I did not come here prepared to address a body of engineers on a technical question, as I am entirely incompetent to do so. Being in an official position, and transporta-

tion being a subject which interests the council and the city at large, I am familiar with the city's needs. But the execution of these needs and the scientific problems that enter into them are properly to be analyzed by engineers and by them carried to a solution.

Last year a subcommittee of the council visited New York and learned much of subway building. New York has solved its problem, but some mistakes have been made there. One mistake was in the matter of ventilation. From what we saw, it seems that the difficulties in shoring adjacent tall buildings have been overcome; although there may be a difference in the soil of Chicago compared with the soil of New York. With such problems as these I think the Western Society of Engineers can cope. From the history of the West, I think we can safely depend on the western engineer to be fully capable of surmounting all difficulties.

The great question before the city of Chicago at the present time is that of transportation. Chicago took a great step forward in the traction question in 1907, when an ordinance was provided which resulted in the rehabilitation of our great system of transportation. But, notwithstanding this great improvement in service, at the present time, owing to the very rapid growth of the city, the transportation facilities are again inadequate for the demands. Our city planning has not kept pace with the growth in population. We must plan not merely to take care of the present congestion, but for Chicago's needs five, ten or twenty years hence.

A forcible illustration of forehandedness was presented to the council committee when it visited New York and saw how a private institution, the Pennsylvania Railroad Company, had planned a depot and yards to take care of not only the needs of today but those for twenty-five years to come. Every unit of their plans has been laid out, planned ahead, only waiting for business to develop for each additional unit to be constructed in a reserved place to make one uniform whole.

It behooves us, therefore, to make a few plans on paper before we really commence building, so that when we do build we may have something which will enable Chicago to become the greatest city in this country and perhaps in the world. I have lived in this city for some thirty years, and have great confidence in it. Foreseeing the power of subway construction to completely change the conditions within the city, I realize that to secure the proper system—the system best suited to relieve our present congestion and provide for our future demands—our course must be taken with great precaution and forethought. If we fail to profit by the mistakes made in subway construction in other large cities in this country and several large cities in Europe, we shall be entitled to criticism.

In regard to our needs, I take it that what we want is rapid transit. The city of Chicago is peculiarly situated, spread out on

three sides. At the junction of the three sides is what we term the loop. Every little town has an embryonic loop; a Market Street where you will find a street car circling around two or three of its houses. From such an embryo Chicago has grown. But it has grown past the embryo. Those located in Chicago's loop may not see why they should forego the benefit of having these cars loop around their particular place of business. The advantage looms up in such a large proportion that they cannot see past it. But to the unprejudiced mind,—the one who looks at the situation from a transportation standpoint, and who realizes that the city has extended from 138th Street on the south, to Evanston on the north, and from 72nd Avenue on the west to the Lake on the east,—it is apparent that the old method of transportation is now outgrown. We want a system of transportation which will carry anyone over the city in his required direction as quickly as possible.

Then comes the question of what facilities will best furnish such transportation. First we had horse cars; then we had the cable system; now we have electric cars, and it appears that they are not adequate for the demands. So that in the light of the present street congestion, subways now present the only feasible means of affording rapid transit.

A factor to be taken into account is the increasing average length of car rides. If the demands of the American people are such that a man desires to ride 10, 15 or 20 miles on a 5c fare, if necessary, we must give him that, because the American people generally get what they are after. How can we do it? Again the answer is, by means of subways. Why?

The operating cost on the surface lines in the city of Chicago is about 62½%. That is, out of every dollar of fares, 62½c goes for operating expenses. New York has demonstrated that subways can be operated at 40%. There, then, is the means. Use the subways as a rapid transportation medium and the surface lines as feeders; carry the long-haul travel by a cheaper medium. We ought to avail ourselves of the particular mode of transportation which will give the best results and cost the least. I say "cost the least" despite the initial cost of subways. The initial cost of any enterprise is secondary. I have learned, in business enterprises, that the initial cost is a minor proposition. It is the every-day recurring operating expense which tells the tale, and that can be reduced to a minimum by rapid transit subways.

The greatest length in the city of Chicago is north and south. Build north and south subways, one or two, through the congested territory.

Do not make that territory a dumping place, but carry the passengers through. Those who desire to get off the cars can do so, and those who wish to be carried further north or south, can stay on. The surface lines will be used eventually as feeder lines for such rapid-transit main thoroughfares. Imagine some people at 79th Street desiring to be carried to Evanston in as near a north

and south line as possible. A surface line starts, we will say, at Riverdale or West Pullman, and comes north to 79th Street and Cottage Grove Avenue with a load of passengers. Some of them desire to go only a few blocks further north and a number of them desire to go downtown. Would it not be policy for the passengers who desire to go downtown to take advantage of the subway and arrive at their destination in a very short time, and have the cars earn that 5c fare in the quickest time possible?

The car that has unloaded those people at 79th Street and Cottage Grove Avenue will carry and pick up passengers on the way to the next station of this subway and there again it has accumulated a percentage of passengers that desire to take a long ride. That long ride should be given to those people at the least cost possible; that is, with a system that requires only 40% operating expense as against a system that requires 62½% operating expense.

That is the scheme that is absolutely necessary, and that is my scheme—not my scheme originally, but what seems to be the reasonable scheme, as far as I am concerned. I am not speaking now officially. I am speaking here as a citizen. I am not voicing the idea or the mind of the committee. But from the study I have given this matter it seems to me the only plausible way is to carry our transportation in subways on straight lines, north and south or east and west, or, if you choose, use the diagonal line streets for the carrying arteries, and the surface lines for the feeders for those arteries.

I do not believe in the subway for short-haul travel, with one exception. Wherever the industries of the city have blocked streets so that street-car lines cannot run through, the obstacle ought to be overcome by subways or tunnels. For instance, our entrances into the congested business districts at the south or the north are few. We are surrounded by railroad property, which blocks many streets. These railroads are here, and are here to stay. To cut streets through would harm the city. I always want to go to the point of least resistance; if I cannot get over a thing I will get under it. To the south of the loop we find a large railroad property blocking the way. There would be little difficulty in constructing a tunnel at La Salle Street, which would give an additional entrance. The same condition applies on the north. On Robey Street, at the Stock Yards, there is a short surface-car line to be built, coming from the south to 47th Street, which must turn five or six blocks to the east or west to skirt the Stock Yards. The Stock Yards are necessary to the city of Chicago. I do not think we could get along without them. We could not easily cut Robey Street through them. So in such places subways are necessary for surface lines, to carry lines on in a straight direction at comparatively little cost in money expended on industries destroyed. Otherwise, if we go to the expense of building a subway, we should build one that will provide rapid transit, because the actual benefits of a subway

cannot be realized in one where the cars stop every few blocks. Subway stations should be no closer than each half mile or each mile. We must be careful not to destroy the value of our subway service by too close station spacing. Let the surface lines collect the short-distance passengers. The long-distance passenger can get rapid transit by changing from the surface car to the subway train which will carry him where he desires to go. The short-distance traveler will stay on the surface car and be taken to his destination.

This, in short, seems to me a plan that could be carried out. We all realize that this is not virgin soil for a transportation problem. Chicago already has one well-established transportation system, and to make a radical change of this kind will require considerable time. It took about nine years for the city of New York to build the first installment of subways. History may repeat itself and we may have considerable trouble, but I hope that with the aid of the engineers and the men who will apply themselves to solve the problem of the city of Chicago, we shall surmount our obstacles.

Tomas F. Deuther (Sec'y North-West Side Commercial Asso'n.): Mr. Bartlett, in the opening of his discussion, said, the need of a system of subways in Chicago has been so thoroughly presented by others that he would not dwell on that point. I would like to know what engineers ever demonstrated the necessity for subways? Bion J. Arnold, in the beginning of his report on subways dated January 31, 1911, said: "No attempt has been made to show in this report the necessity for subways, for it is taken for granted that on account of the present congestion, at times, of the *surface line cars* and elevated trains in the business district, as well as the apparent demand for the removal of the elevated loop structure, that subways are desired, regardless of whether they can be justified from a financial viewpoint or not." He outlined a system of subways, but his own declaration shows that the need of subways was not considered.

No city in the world has the same conditions as the city of Chicago. What is known as the center of the city is not the center. What is known as the central business district is actually on the outskirts of the city. By that I mean that this business center is away from the center of population and as we travel away from the business center we travel towards the center of population, and vice versa.

Mention has been made here of the railroads hemming in the business district, but I consider the biggest hemming in of the downtown district to be the Chicago River. It is admitted on its face that if the river were not there the spread of Chicago would be in all directions. It is this natural condition, together with manipulation of transportation routing, which the loop interests have taken advantage of in making the loop district what it is today. These big interests have made it possible to erect sky-scraper after sky-scraper

so that they will be profitable. Transportation manipulation and the restrictions from expansion are the cause of the present condition in the business center—a condition which is actually criminal.

On the North-West Side a few years back we studied with great care the question of subways and their relative merits and advantages to the citizens of Chicago at large; we looked into every car line within the city, and also the transportation systems of other cities. New York, with its system of subways, is no comparison for Chicago. Did not Mr. Wilcox, former Chairman of the Public Service Commission of New York, say, when he was here this summer, that if Chicago desires to have a system of subways it must be prepared to build a string of five and six-story tenements along its right-of-way in order to make it profitable?

The first question which should interest the Western Society of Engineers should be the present condition of Chicago and the necessity for subways. No engineer will say that any system of subways will relieve the congestion downtown. Our City Engineer, Mr. Ericson, said in his 1909 report on subways: "In any city there is required a coherent, comprehensive development which will allow of the *free growth* of each section in the direction which its business interests require. If *congestion is to continue in the central district, then the building of subways is required as a natural order of development.*" This means that if increased congestion is what is wanted in the downtown district, then subways are necessary in order to bring it about. Mr. Ericson said, further: "The congestion must continue. Hence the tendency must be more to higher buildings than to spreading over a large area, when the natural order of growth (under such a policy) demands more office accommodations; in other words, *increased congestion*. The *congestion must be further maintained* by centering of railroad terminals, elevated lines and surface systems on the present area occupied by the office buildings."

This means that subways are simply a means to further *increase and maintain and perpetuate* congestion.

Mr. Bartlett's plan brings the present elevated lines and stations into State Street, the limit of congestion today. There is not room enough to walk on the sidewalks. The present loop has its stations scattered on its four sides. Will Mr. Bartlett's plan of putting these stations in State Street tend to relieve congestion on a street that is already over-congested?

The most sensible plan that was outlined, in my opinion, is Mr. Mohler's. Although I do not agree with it, yet I think it has one sensible feature which all other plans have ignored,—it pushes its stations a little further away from the business district.

To actually remove congestion downtown there is only one remedy,—an extreme remedy,—viz., remove from the downtown district all means of transportation and let the people walk into the district from across the river.

Those living on the South Side who come downtown on the Illinois Central R. R., or those who use the Northwestern Railway, do not complain that they have to walk from the Randolph Street station over to La Salle Street and Fifth Avenue; it is good exercise for them. But the average man who owns a home on the outskirts will walk a mile in the mud to the car which takes him downtown and then complain if that car does not take him to his office door. I cannot see why this man does not endeavor to have lines of transportation extended nearer to his home and be willing to walk that mile or fraction of a mile after his arrival downtown and where the streets are not muddy.

There are two plans which have not been touched on tonight. Both are the "downtown subways for the elevated only" which have been advanced by Mr. Ericson. I want to point out the great injustice of these plans aside from the claim that they will add to and intensify congestion, which Mr. Ericson has admitted. The claim is made that we have sufficient money in the 55% traction fund to build these subways—some ten or more million dollars. Who are the contributors to this fund? Do any of the "elevated" patrons contribute one cent towards the fund? Is it not all contributed by the patrons of the surface-car lines? Is it right to leave the present surface systems in the demoralized condition in which they are, and use the money derived from such systems to build up the elevated road system?

Engineer St. John has said that of the amount of nickels spent on surface-car lines but 23% originates to and from the loop. Mr. Ericson puts the percentage at 38, but includes territory west to Halsted Street, north to Chicago Avenue, and south to 12th or 22nd Street. So we can see that over 75% of the patronage of surface-car lines originates in all parts of Chicago outside of the downtown district. The majority of rides are on the cross-town lines, such as Halsted, Ashland, Robey, Western, and the east and west lines like Chicago, North, Armitage, Fullerton, 22nd, 31st, etc. The people in the outlying districts are crying for better transportation facilities. They contribute the 55% fund and their claim should be recognized. No system of subways for the elevated roads should be countenanced with the purpose of using the traction fund to build it.

The subway is purely a transportation question. The actual building of it is an engineering question. The city as a whole should be considered. Is the demand for subways actuated by a desire to build up Chicago as a concrete whole? Take away the loop and what have you left? Simply a lot of little squalid villages, all disconnected, with a few pretty residence sections scattered here and there. Look at Ogden Avenue, with its splendid width. What is it? Look at Cottage Grove Avenue, 22nd Street, Ashland Avenue, 31st Street, Archer Avenue, Elston Avenue, and other streets,—what are they? Remove from Milwaukee Avenue, which is the most prosper-

ous of the business streets in the outlying districts, about half a dozen large establishments, and it leaves nothing in the way of a prosperous thoroughfare to be proud of. Many a country town or small city would be ashamed to own some of the thoroughfares which are called business streets, in the outlying districts of Chicago.

If you could look down on Chicago from an airship, you would be surprised at what you would see. Outside the loop district, the city would present a spectacle of a lot of large dishpans with the elevated embankments of the different railroads surrounding them, all disconnected, but *all* directly connected with the downtown district.

Robey Street should not be considered only a central north and south thoroughfare, but it should be known as a street with a high historical significance and should attract visitors to Chicago. Some may not be aware that at Robey Street and the south branch of the river, Father Marquette had his winter quarters years ago, and that not long ago a wooden cross was dug up in that vicinity which was planted by that venerable missionary. Today a cross marks the spot where Father Marquette sojourned in the wilderness days. Yet this street is cut off at both the north and south branches of the river, thus making three thoroughfares out of it. It has three car lines on it. None of them unite on account of the interruptions caused by the river. If one were at Belmont Avenue and Robey Street and desired to go only a few miles south to North Avenue, he would have to go a number of miles in a sort of horse-shoe fashion to arrive there. This is only one instance of many conditions all over the city where little connecting links are missing.

As a striking example, take the Chicago & North Western Railway Depot of today and its former location. I have a friend who lives in Winnetka whose factory is situated almost opposite the old station. Formerly he could get over to the depot for the 5:05 train and get home quickly. Today he can still see the depot from his office window, but to ride he would have to spend 10c, as there is no transfer system in the loop district, and to walk means 30 to 50 minutes. There is no north and south connection over the Chicago River from Fifth Avenue to Halsted Street, and then the next one is two miles west at Western Avenue.

Referring to Mr. Bartlett's discussion. Although I am against subways, there is one system suggested which can be called a downtown subway. The suggestion is to run a subway from Twelfth Street and the Illinois Central R. R. Depot, west to about Clinton Street, then north and under the river to about Kingsbury Street, that is all. It is a simple subway and would connect the depots, as it would pass the Illinois Central, the North Western, and the Pennsylvania stations, and would be similar to New York's systems, where its subways touch at the big depots. With a subway of this character for surface-cars only, one can readily see that all through-route cars could traverse it and arrive at a point beyond

the loop without going through it. Those desiring to go downtown could transfer onto such lines as would continue going there. All the West Side cars could transfer into it, and through lines could be established to different parts of the city and get through the downtown district speedily. Thus we would do away with a lot of congestion caused by the forced and unnecessary present method of taking many people into the loop who do not desire to go there, at the cost of time and expense to patrons who do desire to go there. Generally speaking, I do not believe surface-car lines can operate extensively in subways, and the suggestion offered is only a small, limited subway, more in the nature of a connection like the tunnels we have under the river.

The assertion was made that Mr. Ericson has said, whether subways come or not it will not mean the removal of the surface lines. The same argument can be applied to the elevated roads and that is why I say the loop structure will never come down. By through-routing all elevated trains, the objectionable features of the loop are removed.

Do you know that the loop district is only 1,800 part of the area of Chicago? Did you ever figure on the value of the land alone in the downtown district? It is said that the value of the land downtown is equal to all the rest of the city and Cook County put together. Do you know what is placing unjust valuation on this property at the expense of the rest of the city? It is the matter of transportation, and it is due to its agency and the much decried loop elevated railway that has made multi-millionaires out of the downtown landowners.

Mr. Bartlett: The only method left to relieve congestion is that of subways, relieving the congestion being in the nature of bringing order out of chaos.

We could use a little more common sense in running surface cars. For instance, it is nonsense to stop street cars every 200 ft., as is done in some districts on the North Side. On the South Side, blocks run eight to the mile, not counting "places," only streets. Cars should stop only every other block, i. e., every quarter mile, instead of every block as at present. That would assist, to a certain extent, because the speed could be increased. The building of subways in the downtown district is not for the purpose of benefiting the loop, although there is no doubt that it will benefit the loop. But there are 600,000 to 800,000 people going into and out of the loop every day, and there is no necessity for turning them loose like cattle at the Stock Yards when they can be handled in an orderly manner. The loop is here. The geographical conditions made it, and so far as I can see it is here to stay. We must carry people where they want to go. If a corporation should build a railroad up through the Arctic Circle to the pole, it would be considered a crazy idea, because nobody wants to go there. People want to come down into the loop district and we should provide the best facilities pos-

sible for this purpose. A ride around the union loop will demonstrate that we must provide some way of getting better service.

As to whether it is right for the elevated companies to use subways constructed with the city's 55%, amounting, as Mr. Deuther says, to \$10,000,000, I would say that, if the elevated companies make proper return, so far I can see there is no objection to their doing that. They would be paying for the use of the money and naturally that is all the city would expect in return for this 55%.

It is not a question of bringing more people in, because I do not think that will be the case, except as the city grows.

Conditions here and in New York are entirely different. There they have a population of 15,000 to the square mile as against about 11,000 here.

Subways cost about \$2,000,000 per mile. No private corporation has yet had the hardihood to come forward and offer to build subways with the hope of making any money on them. When people think the average Chicagoan will walk a mile for the sake of riding in the subway, they are mistaken as he will not do it. The Illinois Central R. R., I think, has the best transportation in the city. After that, the elevated railroad, and then the surface lines, People on the South Side, at least, will not walk more than four blocks to get to the elevated railroad; they may be more active on the North West Side.

As I say, the subways must be built and so constructed that they can make money for the people that construct them. The city cannot go into the business of building subways any more than a private corporation could; at least they should not; and how they can build subways that cost eight times as much as elevated railroads and make money out of them, when the elevated railroads could not make money until in the last few years, I cannot comprehend.

F. E. Davidson, M. W. S. E.: I was one of the committee whose duty it was to abstract the reports which have been published and were read tonight. In studying the reports last winter, I was impressed by the fact that in all cases the authors did not have in mind the greater Chicago of the future. They were planning only to relieve temporarily the congested conditions. It seems to me that any subway system for Chicago should be planned with a view of serving a city with a population of at least 10,000,000. We will have that in a very few years.

It is well recognized that the present so-called loop district is now occupied to at least 75% of its ultimate capacity. Please bear that in mind. It is hemmed in, as has been said, by a Chinese wall of railroad yards on the south, on the west, and on the north. Now, where or how is the business district to grow? We are restricted by the building code to buildings 200 ft. in height, and, based upon all records of our cities, the present loop district of the city of Chicago can only increase about 25% more than it is today. It occurs to me that in planning for subways the engineers and the subway

commission should have in mind a broad, comprehensive plan; that the problem should be approached from the "City Planning" standpoint, rather than from the operating engineers' standpoint, if you will. It is not a question of the ability of an engineer to design a practical subway for a particular street to care for a particular line of cars. There are many men in this room who can do it satisfactorily. That is not the problem. It is the larger problem.

My own idea is that a loop subway should be built somewhere west of the river, go over to Grant Park and then over to the north of the river. I would make that subway large enough to accommodate suburban trains as well as elevated railways and through surface cars. I would take care of all suburban traffic through this loop. I would put the La Salle Street suburban depot and also the Pennsylvania depot south of Twelfth Street. This subway could take care of the C. & N. W. Ry., C., M. & St. P. Ry., I. C. R. R., and in fact all railroads operating suburban trains. It would be a loop to distribute passengers through the city. Inside of this main subway loop any number, if necessary, of smaller cross-connecting subways could be built.

Referring to the engineers' estimates contained in these various reports, I will venture to say that when the subways are built (and they will be built some day), history will show that the engineers' estimates as to the actual costs will be as nearly correct as the preliminary estimates of the cost of the drainage canal. You know how near they came to the exact cost.

About one year ago I was asked, in connection with two other engineers of Chicago, to make a special report upon the cost of taking care of the existing buildings on State Street between Lake and Van Buren Streets, during the construction of a subway, which it was planned to go from building line to building line. Our estimate was in excess of \$15,000,000, and I believe it was quite conservative. Somebody must finance this when the subway is built. There are many items of cost that we do not hear of. Public utilities must be taken care of. Somebody must pay. The question today, it seems to me, is not so much a question of the engineer's work as it is of the financier's work. First plan the subways, having in mind the city of Chicago with 10,000,000 people; then arrange for the money; then there will be no difficulty in finding men who can design the system; any experienced engineer can do that. But first arrange for the money.

William Artिंगсталл, M. W. S. E.: It seems to me that \$15,000,000 for taking care of buildings is very high. I have been taking care of a good many for \$30.00 per foot,—large buildings, at that. I believe it could be done for about \$1,500,000.

John W. Mabbs, M. W. S. E.: It has been asked this evening, "Why does Chicago need subways?" Chicago needs subways for the same reason that she needed to elevate her railways, first, to protect human life and, second, to increase speed.

The subways of Chicago should not be confined to the loop district, but should be designed so as to provide all parts of the city with safe rapid transit. Halsted Street, Ashland Avenue, Western Avenue, Kedzie Avenue, and 48th Avenue should be provided with subways for their entire length just as much as State Street, Wabash Avenue, or Clark Street; and Blue Island Avenue, Milwaukee Avenue, Clybourn Avenue and Lincoln Avenue just as well as Lake Street, Madison Street, or Van Buren Street.

The first requirement of a subway plan for Chicago is that it shall benefit the entire city and not one particular part. Some of the subway plans that have been submitted would concentrate the traffic in the downtown district to such an extent that they would hardly be completed before they would be as inadequate and unsatisfactory as our present systems of transportation.

In order to promote discussion, I will outline, briefly, a plan which might meet the needs of Chicago.

Remove all the street cars from the surface of our streets and give the streets over exclusively to vehicles and pedestrians. This can be done easily by excavating the streets from curb to curb or from building line to building line, to a sufficient depth to provide for the street cars directly below the present street level. This space would also provide for all the public utilities and would be decked over for street traffic. This arrangement would also eliminate the expense of continually tearing up the streets to make repairs in connection with these utilities. These shallow subways should be arranged so as to eliminate all grade crossings. The cars should not stop oftener than every two to four blocks.

In connection with this local system, an express system should be provided on all the principal thoroughfares, which could be on the same level where the streets are wide enough, and on a lower level where they are not. The express systems should have stations not less than a mile apart for connection with the local system and cross-lines.

But this does not complete the subway system that is required by Chicago to take care of its traffic. A still lower level of subways should be provided for freight (not like the Illinois Tunnel, which is only an incumbrance of space)—a system of tunnels sufficient to handle any size of freight cars. This system, connecting with our large commercial and manufacturing concerns, our outer harbor, and all our freight and terminal yards, will soon be a necessity, and if installed it would relieve our streets of an enormous amount of traffic to the great advantage of all concerned.

Some may argue that the cost of such a system would be prohibitive, but this is not the case, for the cost of our present water system or our sewer system would have appeared just as prohibitive if presented to any body of engineers a very few decades ago. Nothing that Chicago requires is prohibitive.

This Society as a body and as individuals should be public spirited enough to endeavor to give to Chicago the plans for the most

comprehensive and flexible system of subways which it is possible to design, and one which shall be adequate for all the future needs of a city destined to be the greatest in this country, if not in the world.

Mr. Bartlett: I think no one questions that the subways can be built. It is only a question of money. We can do practically anything if we have the money.

Mr. Chamberlain: As far as the presentation of the paper is concerned, I want to say, for the Publication Committee, that the committee that worked on it—not the present Publication Committee, but the committee that served last year and took up this work—had to deal with the papers which were before them. Up to the present time the work that has been done in connection with subways has been very largely concerned with where the subways should be constructed and whether they should be constructed, as general propositions.

I want to say for myself, and I think that most of the engineers present who are familiar with construction work will agree with me, that as to the feasibility of building the subways there is absolutely no question. The question as to whether they can be built so as to make a profit is another matter. The committee had to deal with the papers that were given them to abstract. Several of the papers were presented to the Western Society of Engineers and the other papers were reports which were gotten up, generally through the city council and at the request of the city or by engineers employed by the city.

Mr. Block: Just for information, I would say that the council has a supplemental report which answers some of the criticisms which have been made against subway building, and among them some of the criticisms made by Mr. Deuther. I note that Mr. Deuther is doing away with congestion by doing away with transportation. I would like to have him come before our committee some day and make good on those same lines. If he should come before our committee and say there are too many cars on Milwaukee Avenue and because of our having too many cars some ought to be taken off, I think his assertion might meet with some objection from the people on Milwaukee Avenue.

We must transport people where they desire to go. There seems to be a great desire on the part of our business friends to have offices in the downtown loop and naturally they object to walking there. The American generally asserts himself and he generally comes down before our committee and makes the shortcomings of the city known, and there seems to be a great demand for additional transportation rather than the other way.

The only way I can see to stop congestion other than the subway is by reducing the height of buildings and widening the streets. Some years ago Professor Hausmann laid out a system and cre-

ated wide boulevards in Paris. The structures and the buildings there are limited to four or five stories, if I remember correctly.

We are building 200 ft. skyscrapers, and, gentlemen, if we continue and take every available building lot in the loop and put a 200 ft. building on it, we can realize we shall have to have not one but several subways.

The people of Chicago desire to reach their homes in as nearly a straight line as possible.

When it comes to a life-saving proposition, I think we need another kind of a subway; namely, a subway for automobiles. I am very much in favor of subways.

THE ERECTION OF THE MUNICIPAL BRIDGE, ST. LOUIS, MO.

W. H. RADCLIFFE, ASSOC. W. S. E.

Presented May 5, 1913.

The Municipal Bridge or so-called "Free Bridge" over the Mississippi River at St. Louis is the result of several years of endeavor by that municipality to eliminate the railway and highway arbitrary arrangements now imposed on all traffic with the Illinois side of the river. It is located about one mile down-stream from the Eads Bridge and enters St. Louis at the foot of Lombard Street. The west highway approach comes to the street level at Seventh and Papin Streets and the railway enters the Terminal yards at Eighth and Gratiot Streets. The project involves a long east approach on the Illinois side, the location of which and the authority to issue bonds for its completion are problems now agitating the good citizens of St. Louis.

It is the purpose of this paper to present the methods of erection of the three channel spans and the considerations and conditions which led to their adoption. Comprehensive descriptions of the design of the bridge have been published; therefore, as a preface to this discussion, one needs simply to refresh his memory with the general dimensions of the bridge and the local conditions affecting its erection.*

The three channel spans are alike and are 668 ft. 0 in. center to center end pins, 35 ft. 0 in. center to center trusses, and 110 ft. 0 in. center to center chords at maximum height. These are the longest simple truss spans ever constructed. Each span weighs 4,647 tons.

Provision is made for a double-track railway on the lower deck, and a double-track street railway, a highway, and two sidewalks on the upper deck. The trusses are Baltimore bow string type with the diagonal members approximately parallel. This produces varying panel lengths, and while desirable in many ways, it makes complications for the erector. There are eighteen panels per span varying in length from 30 to 48 ft. For convenience of identification, let us call the west span, *i. e.*, the one on the St. Louis side, Span 1; the center one, Span 2, and the one on the Illinois side, Span 3. The center line of the bottom chord is 105 ft. above low water on the Government gauge at St. Louis.

All three channels are navigable, the width under Span 1 being lessened by the St. Louis levee, and that under Span 3 by the Pittsburg dyke on the east side. In fact, the location of the bridge is perhaps the most constricted point along the whole St. Louis water

*For fuller information as to the history and design of the Municipal Bridge, see an address by Chas. W. Talbert before the Illinois Society of Engineers and Surveyors at East St. Louis, Illinois, January 26, 1911, and articles by S. W. Bowen, in *Engineering News*, March 16, 1911, February 8, 1912, and January 16, 1913.

front. The current sets to the east and consequently the channel under Span 3 is the deepest and subject to the most violent scour. The maximum depth experienced in this channel was 45 ft. below low water. The variation of scour amounted to 25 ft. In the other two spans the maximum depth was 25 ft. below low water and the changes in the bottom were unimportant. It was necessary to begin on Span 3 because of the lack of yard room on the Missouri side; therefore it was imperative that the falsework be worked out in great detail. We could not depend on the two spans where the water was relatively shallow to acquire experience.

In making the falsework design, the cut-off was fixed at 25 ft. above low water on the Government gauge. It was assumed that the maximum loading on any one bent would occur after the truss had been set beyond that point (but the span not coupled), the



Fig. 1. General View from Illinois Shore

second deck traveler erecting the second deck over the point in question and a heavy chord section passing through on the lower deck. The loads considered were: weight of steel, reaction of second deck traveler, weight of falsework itself, camber blocking, railroad tracks, moving load on railway deck, wind on train and steel and an empirical allowance of 25% of the weight of each of the adjacent panels of steel to compensate for possible settlement. In figuring wind pressure, an assumption was made of 20 lb. per sq. ft. on the vertical projection of each truss and the floor system, and on the train passing through. Under these conditions there was a momentary maximum figured load of 19 tons per pile on some piles, which made it desirable that the piles in deep water be braced under water.

The framed timber bents were two stories high and the maximum figured load on a braced 12 in. by 12 in. post 32 ft. long was

97,500 lb. The working stress used for timber in bearing was 1,600 lb. and fiber stress in bending was 1,200 lb. The falsework bents were designed to come under the panel points. All pile foundations were in double rows at each panel point, the rows being spaced 3 ft. 0 in. centers under bents L-1 to L-3 and 8 ft. 0 in. centers under bents L-4 to L-9. In the framed timber stories a combination of eight and ten vertical posts per bent was used. Bents L-1 to L-3 had ten vertical posts and were single bents. All of the remainder were double bents, L-4 and L-5 having eight vertical posts, and L-6 to L-9 each had ten vertical posts. The double bents were tower braced and all bents were connected longitudinally by 8 in. by 12 in. sash and rod cross bracing. The stringers under the steel were 15 in. 42 lb. I beams and those under the traveler were 20 in. 65 lb. I beams, the number depending on the loading of the respective panels. The design required for each span 608 piles, 760 M ft. B. M. framed timber, 372 tons of I beam stringers and 142 M ft. B. M. camber blocking. Material for two spans was provided. The piles were long leaf yellow pine 18 in. butt, 8 in. point.

The piles provided for Span 3 were 70 to 100 ft. long with the majority 85 to 100 ft. These extreme lengths made it virtually necessary for a representative to select the individual sticks in the woods. Span 3 required 47,436 lin. ft.; Span 2—44,119 lin. ft., and Span 1—34,101 lin. ft., making a total of 125,656 lin. ft. driven. The framed timber was long leaf yellow pine, the important members being merchantable grade, *i. e.*, full size and heart all four sides of its full length. The bracing was purchased under square edge and sound specifications.

The piles were delivered to the river by means of a tramway with a stiff leg derrick at the river end. They were driven by two floating drivers with 70 ft. leads, using No. 1 Vulcan steam hammers. A combination of 30 blows per ft. and 30 ft. penetration was sought in Span 3. Driving was followed by capping and bracing and a diving crew was put on the submarine bracing. For submarine bracing extra piles were used to form cross bracing, bolting them to the piles of the bents under water.

By running the timber through a mill and delivering at the water's edge, already squared, cut, bored and match-marked ready for assembling, a distinct saving in cost of framing was effected. It was assembled in quarter bents on scows under the transfer derrick. The scows were then towed to the front and the quarter bents set in place as one piece by the falsework traveler. This traveler was a through two-boom viaduct traveler with 50 ft. masts and 70 ft. booms, having a capacity of 20 tons per boom. It operated on the lower deck of the bridge and set the falsework, camber blocking, and floor system of the spans.

A suitable location for yarding steel and timber was a serious problem, and the topography of both sides of the river for several miles back from the bridge site was studied carefully. It was cer-

tain that practically all of the steel would be delivered before any of it could be erected and it would be in the yard during the spring season of high water. There were records of high water stages of 38 ft. above low water and practically none of the available locations for yards were over 30 ft. above low water. A site was finally chosen 2,500 ft. from the east end of the bridge site on the Illinois side which was from 32 to 35 ft. above low water. This site was carefully mapped out on the drawing board and the steel members, sawmill, falsework timber, and piles were definitely located. Then the ground was surveyed and staked out so that as the material arrived it was unloaded and yarded according to this prearranged plan. The heavy chord sections were unloaded under derricks and a derrick handled the timber through the sawmill. The other steel members were yarded by means of locomotive cranes.



Fig. 2. Chord Sections in Yard

When needed at the bridge the steel was reloaded, switched to the bridge site, and hoisted to the bridge level by means of a specially designed material hoist. This was composed of two gantry towers superimposed on two parallel lines of trestle with the track on the ground running between them. A parallel track on the top of one trestle and on the lower bridge deck level ran under the gantrys. The span of each of these gantrys was made by using a 31 ft. deck plate girder span, and the towers were of wood. Trucks carrying electric hoisting engines were mounted on tracks on the girders. One gantry was fixed and the other was movable. The heavy chord sections were handled in the yard and lifted to the bridge deck level by means of the hitch angles provided for erecting these members. They were loaded on cars on the bridge level, and were switched to the front by an industrial locomotive. The

smaller steel members, ties, blocking, etc., were loaded on cars in the yard in precisely the order needed at the front, and the cars and contents were hoisted bodily to the bridge deck. Stirrups were installed around the trucks of the cars in this service to facilitate hoisting and were designed so as not to interfere with the operation of the cars.

The traveler for setting the trusses was a three-bent gantry, operating on standard gauge tracks on the falsework outside the trusses. It has a clear opening of 45 ft. 6 in. wide by 124 ft. 6 in. high and was 141 ft. 10 in. high over all. The bents were spaced 40 and 46 ft. respectively. It was designed to hoist two 85 ton sections with an empirical impact allowance of 100% to care for any possible complications due to snarling of rigging and an allowance of 50 lb. per sq. ft. wind pressure on all exposed surfaces. All the

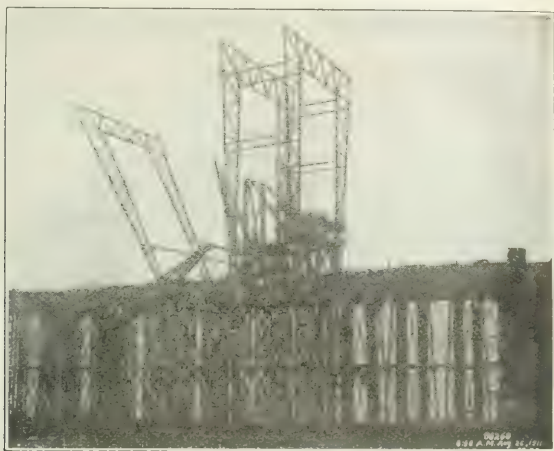


Fig. 3. Erecting Third Bent of Gantry Traveler

members except the lifting beams and longitudinal cross bracing were long leaf yellow pine with steel connection plates and splices. The main lifting beams were each composed of two lines of 24 in. 80 lb. I beams and the auxiliary beams of one line of 20 in. 65 lb. beams each. The heavy lifts were all made from six fixed hitches, three on each lifting beam. Each top chord section of the bridge had provision for two hitch angles. The horizontal projections of the distance between them, when the chord was in place in the structure, corresponded with the location of two of the hitches on the lifting beams of the traveler.

The method of erecting the gantry traveler was a radical departure from the usual practice. A tripping bent was provided 38 ft. high, composed of two towers with bracing between in a plane that would clear the floor system when the traveler bent was up

and the tripping bent down. The three bents of the traveler were assembled on the floor system and falsework, and the tripping bent set up by the falsework traveler. Four 6-sheave blocks were lashed to the top of the towers and reeved into single blocks lashed at various points on the legs of the bent to be lifted. A strain was taken on this tackle and the various leads clamped off with Crosby clamps. This produced in effect a rigid structure. The lifting falls were 13 parts, each hitched to the top of the tripping bent and connected to other sets of falls which ran to an anchorage back of the pier. The leads from the lifting falls ran back on the level of the traveler run to the engines which were anchored back of the pier. The first bent was raised and guyed, and the falsework traveler passed through it and set up the tripping bent on the second, while the falls serving as anchorage were played out to meet the new condition. This was repeated for the third bent. The whole operation had been laid out on the drawing board in advance and the location of all guys had been determined before the bents were raised.

Camber blocking for the first one-half span erected was located by adding to the elevations of the centers of the bottom chord pins on the line of no stress, an amount deduced from an empirical formula which allows $\frac{1}{4}$ in. for each joint of timber in the falsework and camber blocking, and $\frac{1}{8}$ in. for each 20 ft. of height of vertical posts. The settlements of the first one-half span under erection were carefully observed and tabulated and a revision of the camber line was made based on this experience. The success of this method was evidenced by the fact that in no case did the pins drive excessively hard.

Span 3 was erected on camber blocking and was lowered by splitting out the blocking until it gradually crushed. As a substitute for blocking, sand jacks were proposed. A jack was built and tested in the yard under a loading of 215 tons of eyebars. In Span 2 eight of the jacks were put into service and worked successfully, replacing 38 M. ft. B. M. of camber blocking. In Span 1 sixteen jacks were used, one under each main panel point, replacing 76 M. ft. B. M. of camber blocking. Span 3, which was erected entirely on blocking, was lowered in 1,192 man-hours, while Span 1 required only 460 man-hours. Of the last named figure, 410 man-hours were consumed in splitting out blocking under intermediate points and 50 man-hours in lowering the span after it rested entirely on the sand jacks. The jack was composed of a cylinder 48 in. in diameter by 24 in. deep, riveted to a plate on the bottom to form a box. A wooden plunger was used 26 in. deep. The sand was raked out through four gates, each 6 in. square, on the sides. No attempt was made to make the sand flow out or to flush it out, as it was found in our preliminary experiments that this was impractical in a large and relatively shallow box because of the tendency of the sand to form an arch and choke. The sand was raked out and the load was under perfect control at all times. The flow from

any one gate could be stopped entirely by simply closing the gate. The jacks were designed for a pressure of 243 lb. per sq. in. on the plungers.

Erection with the gantry traveler started September 11, 1911. A most unusual flood condition appeared during the early part of October. The center tower and the east half of Span 3 had been erected and the gantry traveler had moved to the extreme east end of the span when the situation became serious. In Span 2 all the piles were driven, and half the falsework bents, together with the floor system, were in place. On October 5th, when the stage of the river reached 18 ft. above low water, erection operations were suspended and all hands turned to protecting what had been erected from the ravages of the river. Three shifts were organized to clean out drift from the falsework, repair it where necessary, and put in riprap and sand bags in an effort to keep the bottom from scouring. For some days previous daily soundings had been taken wherever possible and they were platted and



Fig. 4. Erection of End Post

studied. The west half of Span 3 was seriously threatened. On the bridge level the falsework was forced out of line $13\frac{1}{2}$ in. Piles started to scour out, and because the current was so strong and the water so deep it was impossible to redrive them. The crest of the flood passed on October 8th with a 19.6 ft. stage, a depth of 65 ft. of water under the west half of Span 3, a current of 10 miles per hour and a scour it was impossible to stop. We were able to make soundings between the bents only by putting a 1,000 lb. cast iron ball down from the runner line on the boom of the derrick barge. When a diver tried to go down the cable attached to this ball, the force of the water against his body lifted the ball from the bottom and started downstream with it. Rock as large as a man could handle with a float attached as an indicator moved downstream as far as the float could be seen. The only thing we could get to the bottom was a bundle of half a dozen sand bags roped together tandem. While they probably

November, 1913

reached the bottom, yet so far as actual protection to the falsework was concerned, I doubt if they were of any material value. The scour in the west half of Span 3 ranged from 20 to 26 ft. The water subsided slowly, the damage to the falsework was repaired, additional piling was driven, and erection of Span 3 was resumed on October 19th. Span 3 was coupled up on October 26th and swung free of falsework on October 31st.

The work of clearing the channel was started immediately. As Span 2 was closed, the Government would not permit any work whatever in Span 1 until Span 3 was entirely clear. It was necessary that one span be free at all times from obstructions of any kind. The falsework on Span 3 was match-marked, lowered in sections of one-quarter of a bent and rafted. A pile-pulling



Fig. 5. Erection of Top Chord Section, Span 3

apparatus, consisting of a tower on two scows arranged catamaran fashion, was built. The scows straddled the pile bent to be pulled, and the tower carried rigging of sufficient strength to pull the piles out bodily. This apparatus, being more easily moved, permitted of greater rapidity in hanging falls from the floor of the span than the usual method. Span 3 was cleared on November 22nd and work began immediately on falsework for Span 1.

In the meantime the gantry had started the erection of Span 2 on October 31st; the span was coupled up on December 5th, and swung free of falsework on December 8th.

It now became evident that Span 1 must be erected during a period of danger from ice due to the time lost on account of the October flood. Fortunately this span was more easily protected

from ice than either of the other two. The foot of the levee at a 10 ft. stage, which was about the average at that time, was approximately 225 ft. east of the center line of the west pier of the bridge. This left about 435 ft. of falsework to protect. A shear boom was built upstream at an angle of about 30° with the shore line to deflect running ice into the center channel. This installation consisted of pile clusters of three piles each, spaced 50 ft. apart, and connected by a boom of piles chained together. It proved very effective. An extra heavy falsework tower was built on the levee at the sixth panel point from the west pier, the tower being of sufficient strength to carry the load of the span in case the falsework east of it went out before the span was coupled. If this had happened, there would have been a reversal of stresses in some of the truss members, and those which were tension members were reinforced with timber sufficiently to make them carry the load.



Fig. 6. Gantry Traveler Erecting Span 1

The erection of Span 1 by the gantry started December 20th. As this was progressing we were making special efforts to clear Span 2 so as to minimize the possible loss of falsework material. On December 31st the channel became gorged above and below us and we were forced to discontinue operations under Span 2 because of the mass of running ice. We had salvaged all of the squared timber and had pulled all but about 80 piles. The channel was practically frozen over on the day following. On January 20, 1912, a slight rise caused a movement of the ice pack with a river stage of about 12 ft. Our shear boom was destroyed, but the ice behind it was frozen so solidly the falsework in Span 1 received relatively slight damage. Another movement seemed imminent and the erection of Span 1, which had been seriously de-

layed by weather conditions, was rushed to completion. The last pin was driven at midnight on January 24th, and the span was swung clear of the falsework at 11 o'clock p. m. January 25th.

The big ice movement, however, did not occur until February 3rd, which gave an opportunity to salvage practically all the falsework material.

The work was erected by the regular forces of the American Bridge Company of New York, and pursuant to the policies of the company the processes and equipment were worked out and designed by the best available specialized talent in the service of the company. The writer is deeply indebted to all who coöperated on this work.

DISCUSSION.

F. W. Dencer, M. W. S. E. (Chairman): I am sure we are grateful to Mr. Radcliffe for the very careful preparation he evidently made in writing his paper.

The details of the approach to the channel spans described in the paper were prepared at Gary, but before this work was started, the author went over the general drawings and pointed out the difficulties of erection that he anticipated would be encountered, and of which an ordinary draftsman would have no knowledge. This helped very materially to secure good results in preparing the details for the bridge.

Question: Is there any prospect of finishing the east approach soon?

Mr. Radcliffe: The east approach has been delayed by politics, and I believe each time the city has voted on a bond issue, it has voted it down harder than it did before. Formerly the Socialists and labor unions were opposed to the bond issue, but the last time, the Democrats took a hand in the matter. I think they want the honor of completing it, so the chances are good that the completion will be authorized very soon.

Question: Is the bridge owned by the city?

Mr. Radcliffe: It is municipally owned and the interest on the investment is a very considerable amount. There has been a good deal of opposition to the bridge as originally designed. I think one real-estate man wanted to put it all over the city of East St. Louis and come out on the northeast some place beyond the track owned by the Terminal Transfer Railway. Therefore it is not at all certain where the east approach will come to ground, but I think there will be a compromise whereby the location will be settled this year.

Mr. Dencer: I would like to know a little more about the masonry piers. What methods were used in putting in the foundations and how far down do they extend?

Mr. Radcliffe: As I remember it, the east pier of Span 3 is some 50 ft. below the river bottom, or about 95 ft. below datum.

It extends to bed-rock. I will ask Mr. Smith if he remembers the distance.

D. T. Smith: In pier No. 4, the pier farthest east of the bridge, the bottom of the cutting edge of the caisson was stopped at 104 ft. below datum. That pier has the greatest depth and the rock rises gradually towards the west so that at the west pier the depth was 70 to 75 ft.

Question: As I remember it, one of these piers canted over, changing the detail.

Mr. Radcliffe: It did not change the detail of the steel. I think the upper masonry courses were changed somewhat to take care of that, but it was not a serious matter, and did not affect the steelwork in any way.

Mr. Smith: It resulted in the top of the caisson being about 6 in. off, as I remember it, so that the masonry above the top of the caisson was not exactly square with the caisson or with the concrete base of the caisson.

Mr. Dencer: Were the piers set by pneumatic caissons?

Mr. Radcliffe: Yes. A steel cutting edge with timber above, was used.

Mr. Dencer: Were the pier facings above, granite or concrete?

Mr. Radcliffe: They were concrete, with Bedford limestone facing. The capstones were granite and the cutting edge of the toe was faced with granite.

Question: From your experience on this bridge, would you think a still longer span single-truss bridge is practical?

Mr. Radcliffe: I think such a bridge is entirely practical. The only element of uncertainty is in the floor system. In order to take up the stretch in the floor system, fillers were provided. In some cases we used them and in some we did not.

Question: Could you not provide for a part of that stretch in some other way?

Mr. Radcliffe: In a longer span, I think there would have to be some other method than fillers.

Question: Based on your experience with the St. Louis Municipal Bridge, what is your opinion as to the length of a bridge which can be erected as a simple truss, as far as the erection is concerned, aside from the matter of economy?

Mr. Radcliffe: I think there is no limit for length, if there is a good river bed. We had a very treacherous river bed in Span 3.

Mr. Smith: One feature of those piers not mentioned is that the interior of the piers, the concrete interior back of the facing, was not solid, but was arched over the top, and the interior cavity ran down, I believe, to datum, so that the walls of the piers were

simply shelves on the arch, deep enough on the top to distribute the pressure from the castings to the walls of the pier.

Mr. Dencer: I think it would be of interest to hear something of the workmanship of the bridge, and especially in regard to the approach to the channel spans. Mr. Tompt had charge of preparing the details and we would like to hear from him as to the workmanship of the bridge.

Alfred T. Tompt, M. W. S. E.: All holes are reamed and all the main gusset plates are edge planed. Outside of that it is the usual shop work for this class of work.

Question: What rivet value did you have?

Mr. Tompt: I think it was 10,000.

Mr. Dencer: I will ask Mr. Casper if he will not tell us something about the general shape of the columns and how the stringers are framed into the cross girders?

Mr. Casper: Each column section was made up of three plates and eight angles; that is, two built-up channels with a connecting diaphragm in the center.

Question: Was there any difficulty because of the steel rails being connected directly to the stringers?

Mr. Radcliffe: There was no particular difficulty in the span, but there was some on the highway deck of the approach on the curves.

EXCURSION OF THE WESTERN SOCIETY OF ENGINEERS TO EVANSTON, ILLINOIS

An excursion was held by the Western Society of Engineers on the afternoon of October 11th, to visit the water filtration plant of the City of Evanston, and the Wilmette pumping station of The Sanitary District of Chicago. Some sixty members attended, going out on a special car on the elevated railroad. The crowd was met with automobiles to take them to the work.

The filtration plant is being built for the City of Evanston by the Norwood Engineering Company, Florence, Mass., the Macdonald Engineering Company being the sub-contractors for the concrete and building work. Messrs. George W. Fuller and Langdon Pearse are the engineers for the city.

The party was welcomed by Mr. J. R. Smart, the mayor of Evanston, and Mr. J. H. Moore, Commissioner of Public Works.

The filtration plant is located on the corner of Lincoln Street and Sheridan Road, and is of the rapid filter type. It is being built about 300 ft. from the existing city pumping station. Three low lift centrifugal pumps, connected by gears to DeLaval steam turbines, will take the low lift water from the existing suction wells of the present pumping station, and force it through a Venturi meter into the mixing chamber of the filtration plant. The mixing chamber has a total capacity of approximately 170,000 gallons, giving a nominal period of twenty minutes. This is thoroughly baffled to give velocities around 1 ft. per second. The coagulant sulphate of alumina will be added at the entrance to the mixing chamber. The water will then enter the settling basins, which have a combined capacity of 831,000 gallons, giving a nominal period of sedimentation of one hour and forty minutes. Each basin is to be constructed entirely of reinforced concrete, and divided by two baffles into three bays. The coagulated water will pass onto the filters, of which there are six units, with an aggregate filter surface of 4,425 sq. ft. The filters will be grouped on both sides of a pipe gallery, over which an operating platform will be built. The filters, head house and chemical storage, as well as laboratory building will be built over a covered filtered water reservoir, the roof of which is made up of concrete groined arches, 6 in. thick at the crown, the columns being spaced 12 ft. 6 in. at center. The filtered water basin is divided into two parts, with a total capacity of about 2,000,000 gallons. Provision is to be made for adding both coagulant and chloride of lime as may be required.

The visiting party was shown the interior of the filtered water basin, and one of the concrete filter boxes which had just been poured. Very favorable comment was made on the appearance of the work, the excellence of form details, and the general lay-out of the contractor's plant, with the storage bins for gravel and sand, fed by a belt conveyor; also the carpenter shop with band and circular saws, and other equipment for making forms. There was

also in progress the excavation of the settling basins, where a small Thew steam shovel was filling two yard bottom dumping carts, with which the material was being hauled out of the excavation.

The party then visited the Pumping Station of the Sanitary District located on Sheridan Road at the north end of the north shore channel of the Sanitary District. This pumping station is a remarkable combination of bridge, pumping station and lock, and is an attractive structure, faced with Bedford lime stone. The interior of the pumping station is lined with white tile, and the floor is of red Welsh tile, making a very effective interior. The visitors were shown the entire pumping equipment, transformer room, and trash racks as well as the lock. The pumping station contains four screw pumps, each of capacity 250 cu. ft. per second, at 75 revolutions per minute. The pumps are geared to motors of capacity of 150 h. p. each, the motors being operated by electric current, 3 phase, 60 cycle and 440 volts. The diameter of the screws are approximately 9 ft., the screws being set at the throat of a water way for each pump, extending under and through the foundation of the building. Two pumps were running at the time of the visit. The lift is $1\frac{1}{2}$ to 4 ft.

LANGDON PEARSE, M. W. S. E.

IN MEMORIAM

M. H. DANCE, M. W. S. E.

Died December 19, 1912.

M. H. Dance was born in Trenton, Tennessee, in 1878, where he attended school, completing his engineering education at Memphis, Tennessee.

Mr. Dance entered the service of the Illinois Central Railroad Company as a Masonry Inspector in the summer of 1902, at Jackson, Mississippi. He was transferred to Memphis, Tennessee, in 1903, and placed in charge of the construction of the Iowa Avenue subway at that point, also the construction of an arch under the south yard at Memphis, which was finished in the spring of 1904. He was then appointed Building Inspector on the new shop buildings under construction at South Memphis. Upon the completion of this work, in September, 1904, he was sent to Gilbertsville, Kentucky, as a Masonry Inspector on the construction of the Tennessee River bridge. This work involved the construction of six concrete piers and two abutments, also the erection of two 150-foot and three 300-foot simple steel spans and one 450-foot steel draw span, together with the approaches. Mr. Dance's work at this point included the inspection of concrete and the erection of steel. This work was completed in the spring of 1905, after which he was sent to St. Louis Division as a Masonry Inspector in charge of repair work on that Division.

In December, 1905, he was transferred to Port Gibson, Mississippi, to take charge of the reconstruction of the bridge over Bayou Pierre, which work consisted of the construction of three masonry river piers, raising two miles of track, construction of creosoted pile trestle approaches and the erection of two steel spans.

On the completion of this work, in June 1907, Mr. Dance was promoted to the position as Assistant Engineer and placed in charge of masonry construction on Southern Lines, which position he held until August, 1909, when he was transferred to New Orleans on the terminal work at that point.

On September 1, 1910, he was sent to New Orleans under Division Engineer E. I. Rogers, on construction of the new Poydras Street Terminal work, and was given complete charge of this work upon the resignation of Mr. Rogers, carrying the work forward to completion. This work included the construction of five reinforced concrete and brick freight houses, together with the necessary team and track facilities.

When the above work was completed, he was placed in charge of the construction of the new mechanical terminal at Champaign, Illinois, which he successfully completed in June, 1912.

He was then sent to Centralia, Illinois, in charge of the large mechanical terminal which the railroad company was about to construct at that point. This work consisted of the construction of a 48-stall round house, turntable, cinder and inspection pits, machine shop, boiler shop, power house, store house, freight car repair shops, coal chute, water, sewerage and other minor facilities, together with the necessary track work. Mr. Dance handled this work with remarkable success, and had actually completed it, when the motor car upon which he was riding when returning from work, with two of his assistants, was struck by an engine returning from the new yard, instantly killing Mr. Dance and slightly injuring his two assistants.

His services with the Illinois Central Railroad Company, extending over a period of eleven years, marked a steady advancement. He was recognized as a man of exceptional ability in his chosen profession, and his integrity and fair mindedness were appreciated by all those with whom he came in contact. His death comes as a great loss to the railroad company. He is survived by a wife and daughter.

Memoir prepared by the following committee: A. S. Baldwin, H. H. Hadsall, F. L. Thompson,

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Extra Meeting, October 29, 1913.

An extra meeting of the Society (No. 836), being a joint meeting of the Electrical Section, W. S. E., and the Chicago Section, A. I. E. E., was held Wednesday evening, October 29, 1913, in Fullerton Hall, Art Institute. Mr. R. F. Schuchardt, chairman of the Electrical Section, W. S. E., called the meeting to order at 8:05 p. m. and introduced Mr. L. A. Ferguson, Past President of the American Institute of Electrical Engineers, to preside over the meeting. Mr. Ferguson introduced Dr. Charles P. Steinmetz, of Schenectady, N. Y., who addressed the meeting on "Instability of Electric Circuits." It was estimated that there were more than 400 in attendance.

The meeting adjourned at 9:30 p. m.

Regular Meeting, November 3, 1913.

A regular meeting of the Society (No. 837) was held Monday evening, November 3, 1913. The meeting was called to order at 8:20 p. m., Mr. B. E. Grant, Second Vice President, presiding, with about 60 members and guests in attendance. The minutes of the preceding meetings were not read, as they had been published in the Journal; but the Secretary reported from the Board of Direction that at their regular meeting of October 3rd the following had been elected into the Society:

Wm. Herbert Warner, Chicago, transferred from Junior to Associate Member
Arthur Thomas Pravidza, Chicago, transferred from

	Junior to Associate Member
Joseph Otto Holzinger, Chicago.....	Associate Member
Frederic D. Sturges, Evanston, Ill.....	Junior Member
Alexander Henderson McIntosh, Chicago.....	Associate Member
Thomas Kenneth Myler, Chicago.....	Junior Member
Herbert Mertz, Chicago.....	Junior Member

And that the following had applied for admission into the Society:

Harvey John Carlson, 6702 Greenfield Avenue, Milwaukee, Wis.

Jerome Aaron Moss (transfer), 104 N. Wabash Street, Wheeling, W. Va.

George Thornton Jennings, 5531 Monroe Avenue, Chicago, Ill.

John A. Goetz, Arcola, Ill.

Lincoln Cook Dodge, 1400 E. Fifty-third Street, Chicago, Ill.

Frank J. Berberich, 310 Bank Block, Ft. Wayne, Ind.

Also that the Board of Direction, at their meeting November 3, 1913, had elected into the Society the following:

Harvey John Carlson, Milwaukee, Wis.....Junior Member

Jerome Aaron Moss, Wheeling, W. Va., transferred to Associate Member

George Thornton Jennings, Chicago.....Junior Member

Lincoln Cook Dodge, Chicago, Ill.....Associate Member

And that the following had applied for admission into the Society:

William Edward Graham, Gary, Ind.

Alfred Luebeck, Chicago, Ill.

Thomas Allen Banning, Jr., Chicago, Ill.

A. Edward Sackerson, Chicago, Ill.

Joseph E. Love, Chicago, Ill.

Eleuterio Martinez, Jr., Mexico City, Mexico.

Joseph Frank Ward, Evanston, Ill.

The Secretary also reported that the 100-foot Standard of Length has been finally installed in the basement of the City Hall, Chicago. A portion of the report of the committee which has had this matter in hand, describ-

ing the 100-foot Standard Measure of Length, and its location in the City Hall, was read by the Secretary.

There being no further business before the Society, Mr. Grant, as chairman, introduced Mr. John F. Hayford, M. S. W. E., who gave a very interesting lecture on "Measuring the Earth." This was illustrated by lantern slides. Discussion followed—mostly in the form of questions—and replies from Prof. Hayford, from H. E. Goldberg, E. B. Wilson, F. E. Davidson, L. E. Cooley, F. W. Dencer, J. H. Prior, F. G. Vent, W. C. Bauer, W. F. Smith and B. E. Grant. Mr. Davidson moved a vote of thanks to Prof. Hayford for his interesting and valuable lecture, which was carried.

Meeting adjourned about 10:30 p. m.

Extra Meeting, November 24, 1913.

An extra meeting of the Society (No. 838), being a joint meeting of the Electrical Section, W. S. E., and the Chicago Section, A. I. E. E., was held Monday evening, November 24, 1913, in the Society rooms.

Mr. D. W. Roper, M. W. S. E., chairman of the Chicago Section, A. I. E. E., presided. The meeting was called to order at 8:30 p. m., with about fifty members and guests in attendance.

The minutes of the meeting of October 29, 1913, were read and approved. The Secretary also read a letter from President Williams, of the American Museum of Safety, inviting the Western Society of Engineers to take part in The International Conference of Safety and Sanitation, to be held in New York City, December 11-20, 1913, under the auspices of the Museum.

The Secretary also read a letter to the Chicago Section, A. I. E. E., from Secretary-Treasurer Preston S. Millar, New York, calling attention to the International Electrical Congress, to be held in San Francisco, Cal., September, 1915, in conjunction with the Panama-Pacific International Exposition, and asking the coöperation and assistance of the Chicago Section, A. I. E. E.

The Secretary also stated that at the next meeting of the Electrical Section, W. S. E., to be held December 29, 1913, nominations for members of the Executive Committee of the Electrical Section would be in order.

The chairman then introduced Mr. Lucius B. Andrus, Member A. I. E. E., who presented in abstract his paper (which had been printed in advance) on "Testing of Horizontal Lowhead Water Turbines," at Elkhart, Ind. His remarks were illustrated by some charts and blackboard sketches. The Secretary read letters in discussion of the paper from Prof. R. L. Sackett, Purdue University, Lafayette, Ind., and Mr. J. C. Pinney, Jr., of Milwaukee. Discussion followed from the chairman and Messrs. Wm. B. Jackson, F. G. Vent, Dr. E. W. Lloyd, with replies and explanations from Mr. Andrus.

Mr. H. E. Goldberg moved a vote of thanks to Mr. Andrus for his interesting paper, which was carried.

Meeting adjourned about 10 p. m.

J. H. WARDER, Secretary.

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THIS SOCIETY.

WRIGHT ON BUILDING ARBITRATIONS. A Manual for Architects, Students, Contractors and Construction Engineers. By G. Alexander Wright, Architect, M. A. I. A., Tech. Soc. Pac. Coast, etc. Paper, 6 by 9 in.; 47 pages. Price, \$1.00. For sale by the author, San Francisco, Calif.

WRIGHT ON QUANTITIES. A Plea for a Better System of Estimating Cost of Buildings in the United States. By G. Alexander Wright, author of Wright on Building Arbitrations, etc. Paper, 6 by 9 in. Price, 50 cents. For sale by the author, San Francisco, Calif.

November, 1913

The first of the above pamphlets is a revised edition of a pamphlet first printed in 1894, which has been of great benefit to men engaged in arbitrating disputes over building construction. It contains methods of procedure recommended by the best authorities, together with blanks of forms to use in making reports, etc. The old edition was considered authoritative and the improved edition should certainly find a welcome in the building industries.

The second pamphlet is an outline of the method proposed by its distinguished author to insure safe bidding for building contracts and stop the wild guessing so often the result of the lack of system in estimating work in the United States. Mr. Wright has been a well-known architect on the Pacific Coast for more than 25 years and is the President of the Technical Society of the Pacific Coast. His training was received in Great Britain, where he practiced for many years as a Quantity Surveyor. This pamphlet is intended to show the benefits to be derived from accurate estimating resulting from the taking off of quantities from plans by qualified quantity surveyors, who are under bonds. An American Association of Quantity Surveyors has been formed and the principle of correct estimating will be pushed. A limited number of copies of this pamphlet on quantity surveying have been placed at the disposal of the Secretary of the Western Society of Engineers for free distribution. The request is made that none apply for free copies except those interested as architects, contractors, or estimators in the building business. Those merely curious to have the pamphlet may purchase them of the author. McC.

LIBRARY NOTES

The Library Committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts, the following publications have been received.

NEW BOOKS.

Wyoming State Engineer:

Irrigation Laws of Wyoming, 1913. Pam.

Wainwright, Jacob T.:

An Investigation of the Second Law of Thermodynamics. The New Thermodynamics. Wainwright. Cloth.

McGraw-Hill Book Co.:

Reinforced Concrete Construction, Part II. George A. Hool. Cloth.

Purchase:

Observations in Meteorology, Leonard Jenyns. Cloth.

Our Waterways, Forbes and Edwards. Cloth.

Water, Its Origin and Use, Wm. Coles-Finch. Cloth.

A Treatise on the Theory of Elasticity, 2 vols. A. E. H. Love. Cloth.

MISCELLANEOUS GIFTS.

John F. Wallace, M. W. S. E.:

Report to the Committee on Railway Terminals of the City Council of Chicago, J. F. Wallace. Pam.

Baltimore Sewerage Commission:

Annual Report for the Year 1912. Pam.

S. E. Hendricks & Co.:

Hendricks' Commercial Register of the United States, 1913. Cloth.

J. B. Henderson:

Proceedings, Interstate Conference on Artesian Water, Sydney, Australia, 1912. Boards.

Additions.

MEMBERSHIP

Carlson, Harvey J., Milwaukee, Wis.....Junior Member

Dodge, Lincoln C., Chicago.....Associate Member

Jennings, George T., Chicago.....Junior Member

Moss, Jerome A., Wheeling, W. Va., transferred from

Junior to Associate Member

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No. 10

DOUBLING THE LOAD CAPACITY OF AN OLD IRON RAILROAD VIADUCT

W. T. CURTIS, M. W. S. E.*

Presented June 9, 1913, before the Bridge and Structural Section.

In 1888 the Chicago & West Michigan Railway Company built a wrought iron single track viaduct across the Manistee river located about 100 miles north of the city of Grand Rapids, Mich., at a point now known as High Bridge, and recently established as a postoffice and flag station, on the Pere Marquette Railroad, which system absorbed the old Chicago & West Michigan Railway Company some years ago.

This viaduct is 1,170 ft. long, consisting in the main of 14 tower spans 75 ft. high by 30 ft. long, supporting 45 ft. spans between towers, and one 150 ft. river span across the main channel of the stream. The 30 ft. and the 45 ft. spans were, in the original construction, simple deck plate girders spaced 8 ft. on centers. The river span consisted of ordinary 150 ft. deck trusses spaced 14 ft. on centers. This structure as built 25 years ago, appeared as shown in Fig. 1.

During the winter of 1911-12, the structure was reinforced for heavier loading and stands today as appears in Fig. 2, taken from about the same point of view as Fig. 1. A comparison of Figs. 1 and 2 shows the reconstructed bridge to be somewhat more massive and substantial looking than the original. Figure 3 is from a photograph taken at a little closer range after reconstruction, in order to bring out more clearly some of the details.

It is the purpose of this paper to describe the method of this reconstruction and its execution. The mathematical features of the work are avoided in this article as being of less general interest than a descriptive treatment of the subject.

The original structure was designed for a loading about equal to Cooper's E-25. The rolling stock gradually became heavier and heavier, so that in later years the bridge was somewhat overloaded.

*Contracting Engineer for Wisconsin Bridge & Iron Co.

In 1911 it was decided by the railway company to put still heavier loading (E-50) on the bridge, thus increasing it to an extent which would be unsafe for the old structure. It remained to either replace the structure with a new one, or to reinforce it, and the latter method was elected as being much more economical.

Mr. J. F. Deimling, Chief Engineer of the Pere Marquette Railroad Company, asked for competitive propositions for both cost and design on the reinforcement, submitting, by way of suggestive



Fig. 1. General View of Manistee River Viaduct, Before Reinforcement.

information, a solution which had been used some years ago on their Mill Creek trestle. This consisted of adding a new line of deck plate girders the entire length of the viaduct on the center line of track, these girders being supported on new independent posts at the center of each bent, as shown on sketch for bents of north approach only, in the upper right hand corner of Plate I, and also on Plate VII. (This scheme was used only on a very small portion of the plan finally adopted, for reasons given later.)

Some tenders were offered on this center girder scheme of reinforcement for the entire Manistee viaduct, but were discarded, partly on account of greater cost but chiefly on account of uncertainty of distribution of load among the three girders, as the old girders on this Manistee viaduct are only 8 ft. centers, making the wood ties so short and stiff as to cause a marked degree of indeterminateness of the distribution of the load among the three girders. A further objection was the rocking or tipping effect over



Fig. 2. General View of Manistee River Viaduct, After Reinforcement.

the new center girder as a fulcrum under imperfectly adjusted or worn ties, the shortness of the ties magnifying this difficulty. (The girders of the old Mill Creek trestle were spaced further apart, which made the new middle girder idea less objectionable in that piece of work.) A still further objection to this center girder scheme of reinforcement was the fact that the erection would seriously interfere with traffic during a long period of time.

Another scheme considered was to reinforce each of the old

legs of the bents by adding another member parallel to it, surmounted with an additional new track girder placed closely along the side of the old girders, making a total of four girders with the old ones. This scheme was discarded as being prohibitively expensive, and somewhat unsightly as giving a pronounced appearance of being patched up.



Fig. 3. Detail View of Manistee River Viaduct, After Reinforcement.

The scheme finally adopted was proposed by the Wisconsin Bridge & Iron Company, being original with the writer, and is shown in Figs. 2 and 3, and also in diagram form, Plate I. The latter shows, in dotted lines, the old or original structure, and in full lines the newly added members.

This design was adopted for its economy, its lesser degree of

indefiniteness of distribution of loads, its far greater general stiffness, its minimum interference with traffic during construction, and incidentally on account of its having a less patched-up and made-over appearance than either of the other schemes offered.

The governing or fundamental idea of the adopted scheme was to convert the upper or deck portion of the viaduct into a series of deep lattice trusses, of which the old girders would themselves constitute the top chords. This was done by adding a bottom chord about 12 ft. below the girders and introducing a Warren web system between the two chords thus formed. These old deck girders are, of course, stiff enough to resist the bending action of the load, and to deliver these local loads to the panel points of the newly formed truss. In calculation, for safety, the old girders were figured both as simple spans between new panel points, and as continuous girders, the worst result being used in all cases. Additional stiffeners were added and cross frames installed as shown on Plate II.

To carry the excess load from these newly formed trusses to the ground, two new columns are added to each bent, starting at the bottom chord of the new trusses and running on an incline down to a new concrete pier built at the center of each old bent. The two new columns thus form a **V** and make the remodeled bent consist of two A-frames, as shown in the typical cross section sketch at the bottom of Plate I, and as shown quite clearly in perspective in Fig. 3.

This construction has the desired effect of virtually lessening the height of the trestle towers by about 12 ft., for the load is now delivered into the towers at the bottom chord of the newly formed trusses (Fig. 3). Furthermore, this system braces the structure longitudinally by virtue of the depth of the new trusses. Also, the new A-frame form of the bents stiffens the structure transversely. The scheme has the further advantage of being capable of field construction with practically no interference with traffic, as the old girders were not disturbed, except for the drilling of holes, etc., in them.

In this manner we preserved for the main length of the viaduct the original two-point-bearing for the ties, which is undoubtedly the best, giving absolute definiteness of load delivery, and doing away with the tendency to tipping or teetering of the ties.

At the river span the system just described could, of course, not be followed, and here a new deck truss 150 ft. long was placed midway between the old trusses. The distance between the old trusses is 14 ft., being thus sufficiently far apart to give longer and consequently more limber ties, permitting of more definite proportioning of loads as delivered from the ties into the two old and the one new trusses, and also minimizing the tipping effect of the ties. In fact, this appeared to be the only reasonable solution of the river span problem, and was the one contemplated in all proposals offered.

The load from the new center river truss is carried to the ground by a new independent straight column as shown for bents Nos. 25 and 26 on Plate VII, and as shown quite clearly in Fig. 2.

The towers supporting the river span, and the three short spans of the north approach to the river span, were originally built with the deck girders spaced 14 ft. centers, the same as the river span trusses, and we therefore reinforced this small portion of the viaduct after the manner of the old Mill Creek trestle, *i. e.*, by the introduction of a new girder midway between the two old ones, in line with the new river truss and, like the latter, supported by a single new independent straight column at the middle of the old bents.

The developing and detailing of any scheme of reinforcement form fully as important a part as the conception of the general or fundamental idea itself. As other duties prevented the writer from taking any very active part in carrying out the execution of the work, that important part was turned over to other departments of the bridge company. The original idea was perfected, developed, and executed by the engineering staff of the Wisconsin Bridge & Iron Company under the direction of their Chief Engineer, Mr. V. Guillemain, a member of this Society, and a good deal of what follows has been compiled from detail drawings and correspondence on file augmented by special correspondence with the bridge company's Assistant Engineer, C. M. Pearson, who had charge of the detailing of the work, and with F. A. Ross, Engineer of Erection for the bridge company.

The new steel was figured as closely as possible in accordance with the American Railway Engineering Association specifications. The old metal, which is of iron, was figured in general at 14,000

lb. per sq. in. in tension, and at 16,000 — $\frac{1}{70}$ — in compression.

Judgment had to be exercised at all times in the application of specifications, this particular piece of work being most highly susceptible for the practical adaptation of that familiar remark which appears on the front cover page of all of Mr. Theodore Cooper's specifications, reading as follows: "The most perfect system of rules to insure success must be interpreted upon the broad grounds of professional intelligence and common sense."

In a remodeling work of this kind it is impossible to escape entirely, indeterminate features, as the engineer is confronted and restricted by conditions as they exist. He necessarily lacks the freedom of ingenuity offered on new work. The problem before us was to double the capacity of the structure, and the general aim throughout was to arrange the new parts so that the old parts would still carry their full share of the old E-25 loading, and so that the new members would make up the difference to bring it up to E-50, with sufficient excess to insure taking care of uncertainties.

One source of indeterminateness which was true of both of the schemes seriously considered was the possibility of improper distribution of load between the two old and the one new piers of each bent. This is always true in the case of a continuous three-point-bearing, but there was no alternative in this problem, as there seemed to be no other way of getting sufficient bearing in the soil than to introduce the new middle pier. As a partial insurance to a proper distribution of loads on the three piers, the new middle pier was surmounted with an adjustable cast iron base (Fig. 4), so sim-

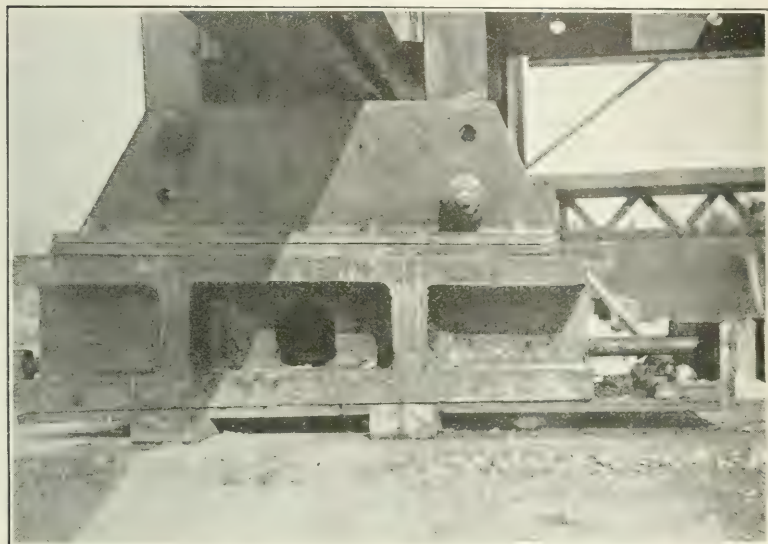


Fig. 4. Adjustable Shoe. Manistee River Viaduct Reinforcement.

ple in its adjustment that a bridge inspector on his annual inspection can, without any assistance whatever, and with no other tools than a good sized wrench, adjust this shoe to take care of any difference in shrinkage or settlement which may appear among the three piers. The sliding surfaces of these adjustable shoes were coated with a cheap and lasting form of lubricant known as "Velvet No. 2." The wedges provide for a vertical movement of $\frac{1}{8}$ in. for a horizontal movement of 3 in. and are controlled by ordinary machine bolts with double nuts. In erecting the wedges, they were set in pairs with the slopes in opposite directions so as to neutralize each other and prevent the entire structure from tending to drift or slide all in one direction.

In Plate III is shown sectional views of the cross frames and hangers between the two old river trusses and the new truss, the latter being somewhat deeper than the old ones. The heavy I beam

shown at the top of the new center truss does not constitute a part of the top chord section proper, it being merely a continuous filler and tie support, in order not to permanently disturb the old top lateral system which was left intact. An entirely new lateral system was added below the old system in the plane of the new top chord. The old laterals are allowed to pass through holes in the web of this 15 in. I beam, only one of the old lateral members being disconnected at a time to insert through this beam, and none being disconnected until the new lateral system directly beneath it was in place. This filler beam was provided with shims for adjusting it to fit the old ties.

A difficulty which presented itself was the difference in deflection between the old shallow river trusses and the new deeper one. This was studied carefully, and the difference in deflection was found to be sufficiently small so that it could be taken care of, to all practical purposes, by making the hangers from the old to the new trusses heavier than was theoretically required. This made the hangers act as equalizers, whereby if one truss should commence to be overstrained it would deflect enough more to deliver the load to the other truss before any actual harm would be done to the former. In this way, the load in any possibly overstrained member would still be so much below the elastic limit load that set deformation was out of the question. It was found that the percentage of overstrain necessary to demand equalization was very low, and that while perhaps this solution of the distribution of the loads would not be considered as the most desirable practice in new designing, it served as a safe and satisfactory solution of the problem at hand.

The expansion of this new center river truss was taken care of by a link construction shown on Plate IV.

The structure being narrow and high, the matter of thoroughly bracing it was nearly as important as the direct loading feature, and while the general form of reinforcement provided for a marked general stiffening of the main run of the viaduct, additional bracing was added entirely independent of the old bracing system, the old system being allowed to remain intact so that both systems are now acting jointly to withstand wind and tractive forces.

For the transverse or wind strains in the 45 ft. spans, new laterals are introduced for the middle panel of the newly formed trusses. See Plates I and II. These laterals terminate at new cross frames introduced at the panel points of the trusses carrying the wind load down to the bottom chord of the old deck girders, from which the load travels through a system of rod bracing in the plane of the inclined end posts of the new deep trusses to the tops of the newly formed A-frame columns. See Plate V. From this point to the ground the A-frames themselves constitute the additional wind or transverse bracing. The 30 ft. spans were similarly treated.

For the wind strain in the river and short approach spans which have the new independent straight center column instead of the **V** shaped columns, no additional stiffness was afforded by the new column, and the old system of rods was therefore doubled.

For tractive force or longitudinal bracing the newly formed Warren side trusses formed sufficient bracing down to the tops of the newly added **V** shaped columns, and the tractive forces are carried from this point to the ground by an entirely new system of bracing in the longitudinal plane of the legs of these new **V** columns. (This is shown in typical side elevation, Plate I.)

The solution of the more general problems, while interesting, led incidentally to problems of more minute detail, which were in themselves fully as interesting as the larger problems, and in some instances were fully as important. The detail drawings for the reinforcement of this bridge covered some 35 sheets, and the scope of this paper will permit of touching upon only a few of the more interesting details.

The new **V** shaped columns in the tower bents are designed to go half on either side of the old bents straddle fashion, and were shipped "knock down," each leg of the **V** being in two parts for each of its sections. The lacing bars were shipped riveted to one side of each section, the other side being connected in the field. Plate V shows these columns. It took careful drafting to insure no interference between the lacing bars of these new members and the old steel work. These new columns were connected to the old tower struts, where convenient, to form a general stiffening to the structure. In the erection of all these new columns the old steel was not disturbed, except for the necessary drilling. This in fact was considered as one of the commendable features of the design.

Connections for the rod bracing between the pairs of reinforcement trusses in the plane of the inclined end posts of these trusses presented a problem which was solved by the use of cast steel hitch brackets, which did away with what would otherwise have been clumsy and fussy detail. One of these hitch brackets is shown in position at the left hand end of Plate VI. In order to avoid the uncertainty of rivets in tension on these hitch brackets, bolts instead of rivets were used in the outermost holes. These hitch brackets were cut with right and left threads, permitting of direct adjustment of the tension rods.

Much trouble was experienced in finding suitable connections of the new wind-bracing rods to the old bents, which were not converted into the double A-frame form, on account of the old bracing being pin connected. Whenever possible, a connection was made, obviating the necessity of removing the old pins, but this was impossible in some cases.

Particular care was exercised to see that the loads from the new intermediate river truss were delivered properly into the columns, and a somewhat complicated detail resulted, as shown in

Plate IV, from which it will be observed that the details are so made, in nearly every case, that the old steel is not interfered with. This, in fact, was the aim of the detail work on the entire structure.

Extra care was exercised in all the details to allow for inconsistencies in the old construction. This was done by providing numerous shims and doing a great deal of field drilling that would otherwise not have been necessary. Plate VI shows details of the 45-ft. deep trusses under the old girders. In the upper right hand corner of this drawing are shown shims and fillers which were provided to adjust the new steel work to the old. The entire job abounded in painstaking work of this character, in order that the new member would fit the old parts to which it should connect, and at the same time clear the old parts with which it was desired not to interfere. The detail drafting alone on this job cost a little over \$950.00 for wages paid direct to the draftsman, exclusive of any overhead expense of any kind.

As previously mentioned, the foundations required reinforcing by the introduction of a new or third pier midway between the old piers, at each bent for the entire length of the viaduct. These piers were of concrete construction resting on piles, there being 12 piles to each of the standard bents, and 20 piles for the special piers under the new river truss. The piles were driven 35 ft. and were so arranged that they could be driven on either side of the old bent without disturbing the old iron work.

Considerable difficulty was encountered on this foundation work, due to the fact that there existed, unknown to the railway company or to the bridge company, an old corduroy road on the center line of the viaduct for its entire length. This road was covered with several feet of sandy silt, which made it very difficult to remove the corduroy logs. In some cases the piles were driven right through the corduroy, in other cases the logs were removed, and in still other cases the logs were cut. One way seemed to be about as expensive as another.

Unexpected difficulty was also encountered on account of the water rising some two feet higher than had been previously known. This upset our calculations for cofferdams, causing much delay and expense.

The method of handling the pile driver was quite interesting. It had to be moved many times to drive the small cluster of piles at each of the bents, each cluster being split into two groups as divided by the old iron bents which stood on the center line of each pile cluster. The pile driver was handled from the deck of the structure 75 ft. above, and was placed at the various points of operation without removing any of the old bracing. This not only saved expense but was better for the structure. The driver was picked up near its center of gravity, tilted over with its legs uppermost and its nose or top thrust between the bracing rods of the structure to the desired point of setting up. In this way it was

moved along from point to point. Very little timber bracing was used at the foot of the driver, which was guyed to the old iron columns of which there were plenty near each set-up. The engine was handled separately from the driver, not being mounted on it. This avoided the necessity of moving the engine as frequently as the driver.

The concrete was mixed and placed in the winter without any unusual expense, aside from the excavation and cofferdam annoyance previously mentioned. Gravel was brought to the site in hopper bottom cars and run out onto the viaduct to a desired point. A few track ties beneath the car were then spread and the contents dropped 75 ft. to the ice below. From the stock piles thus formed the gravel was conveyed over the ice to the final point of deposit, the mixing being done in each case right at the forms. The cofferdams were of the Wakefield type.

The weather was very cold most of the time, but we merely had to be sure that the frost was taken out of the dry material to begin with, for most of the concrete was placed under water and the small portion which protruded could be protected at slight expense with marsh grass and was kept slightly warm by the larger mass of concrete below the ice.

The erection of the steel work was somewhat unusual, and while at first appearing somewhat formidable, it worked out satisfactorily and with reasonable economy, barring delays due to foundation trouble.

The old work was mostly field bolted, which made the occasional temporary removing of old members less expensive. The field drilling and riveting was an expensive item, there being so much of it. There were about 7,000 holes to drill, about 2,000 old $\frac{3}{4}$ -in. rivets to knock out and ream the old holes to $1\frac{1}{2}$ in., and about 28,700 rivets to drive on the job.

The new steel was handled by a derrick car at the beginning of the work, but this method did not prove entirely satisfactory, and the derrick car was later replaced by a locomotive crane (Fig. 4) which gave better results.

The river span was erected with very little falsework. The new steel columns were first erected at the ends of this span. Then the top chord was raised and suspended from the old structure with steamboat ratchets, the turnbuckles being placed so as not to interfere with railroad traffic. All new top chord bracing was then placed, this being connected to the old trusses, and all bottom chord bracing removed. The balance of the new truss was then placed with falsework consisting of but a single wood post at either end, and the truss was kept suspended and controlled with 24 turnbuckles until completely riveted.

The work abounded in opportunities for interferences and misfits between old and new parts, but very little trouble in this direction was actually encountered—so little, in fact, that we were

agreeably surprised, and considered this piece of work as a demonstration of the feasibility of doing this class of reconstruction at reasonable cost.

A word in regard to the condition of the old iron work may be of interest. Our erection foremen reported, early in the op-



Fig. 5. Use of Locomotive Crane.

eration, that they found some old rivets which had to be removed; and some of the old laterals, etc., to which they had occasion to hitch stay chains, appeared to be harder and more brittle than they were accustomed to handling. This led to investigation, and a

chemical and mechanical test was made on the upset stub end of a broken lateral rod, with the following observations:

SAMPLE A.

Manganese	0.05%
Phosphorus	0.405%
Sulphur	0.020%
Silicon	0.289%
Area, sq. in.	0.1979
Elastic limit	not apparent
Ultimate strength, lb. per sq. in.	36230
Elongation in 2 in.	3.5%
Reduction of area	1.97%
Fracture	Coarse crystalline

The above result of test was not satisfactory but the testing laboratory did not consider the sample a fair one as it appeared to have been subjected to abuse due to overloading in service, or possible burning in manufacture when upset.

Additional tests were therefore subsequently made of two samples cut elsewhere from load-carrying metal in the bridge, with the following observations, a mechanical test only being made in these cases:

	SAMPLE B.	SAMPLE C.
Area, sq. in.	0.1979	0.1987
Elastic limit, lb. per sq. in.	41230	42300
Ultimate Strength, lb. per sq. in.	56500	57520
Elongation in 2 in.	12%	16%
Reduction of area	12.2%	23.5%
Fracture	Fine granular	Half silky, half granular

While the metal in Sample B looked a little hard, the observations, taken as a whole, were such as to relieve suspicion as to the quality of fatigue of the iron in the old structure, and no further attention was paid to the matter other than a careful watching for defects, none of importance having been found.

As mentioned, the old structure was field-bolted (with the exception of buck and lateral bracing between the girders), a fact which was not discovered until after the field work of reconstruction had been begun. The owners on becoming aware of this condition at first seriously considered replacing all old field bolts with new rivets. Careful investigation showed the old structure to be in perfect alignment with none of the bolts loose in the slightest degree, although the structure had seen years of service and had been somewhat overloaded in its later years, so it was decided not to go to the extra expense of replacing the bolts with rivets. As a matter of fact, many of the buck and lateral connections which had been riveted originally, were found to be in bad shape on account of loose rivets, the vibration of passing trains having worn deeply into some of the rivets. While it was realized that the points which had been riveted in the old structure were points subject to more severe service than the points which had been bolted,

the investigation satisfied all who participated in it that bolts are in reality much better than are generally considered in ordinary practice. Other observations we have had opportunity to make under somewhat similar circumstances have added evidence to this conclusion.

We were agreeably surprised to find that the detail of the old structure was in excellent accord with the old drawings, and we



Fig. 6. View Through Towers After Reinforcing.

soon learned that the old drawings could be depended upon for accuracy with as full confidence as one would expect in present-day practice. In this feature of the old work, a remark of praise is due the old Detroit Bridge & Iron Co. (since absorbed by the American Bridge Company), who built the original structure a quarter of a century ago. The structure has evidently been well cared for and painted and did not show its age, except by old style detail.

The cost of the reconstruction was, in round numbers, as fol-

lows; these figures including all extras on the work proper and a contractor's profit of 10%, the work having been undertaken on a percentage basis with a fixed maximum limit:

Foundations in place (Ry. Co. furnished gravel free).....	\$10,200.00
New Steel, 455 tons delivered at site (free freight).....	22,400.00
Erection of steel (free transportation of men and equipment).....	11,300.00
Total cost.....	\$43,900.00

which, on a conservative guess, is only about half what a new structure would have cost.

The old structure weighed 496 tons.

DISCUSSION.

I. F. Stern, M. W. S. E. (Chairman): The chair is glad to vouch for the author's training in the particular line of reinforcing described. He left the railroad field a number of years ago to engage in work with a bridge company, and since then has been acting as contracting engineer in getting business for the bridge company. The modern bridge companies act as bridge engineers and usually give their services for the business they get. So it is fortunate, when the railroad companies have not that talent in their own organization, to be able to secure the services of a man like the author, to give such assistance as they need.

It gives me much pleasure to say that the gentleman who trained both the author of this paper and your chairman, is with us this evening. He has probably had more experience in this line than any man in the country. I refer to Mr. W. H. Finley, Assistant Chief Engineer of the Chicago & North Western Ry. Co., and take the liberty of calling on him to speak to us on the subject of reinforcing in general.

W. H. Finley, M. W. S. E.: It is hardly fair for the chairman to call on me in this way. I simply came here to listen to what might be said about reinforcing bridges.

There is no question, as suggested by the author in his paper, but that one must close his eyes, to a considerable extent, to theory and use common sense—if it so happens that he is the happy possessor of that commodity. This was impressed upon me as I listened to the author present his paper. I have had experience in reinforcing bridges of various kinds and realize the difficulty encountered in reinforcing this viaduct.

I hardly agree with the author's statement that the girders acted as the top chord of the truss, but am inclined to think that the bottom flange of the girders may be considered as the top chord of the truss. If I were considering that problem I would probably figure the plate girders for their maximum loading and determine the deflections at the points where the author applied the support; then count upon relieving that much of the deflection in the girders as to bring the stresses within safe limits. But no doubt what he has done will give the same results.

These girders, as I understand it, had 8 ft. centers and the author calls attention to the difficulty of the distribution of the load between the three girders if he had used a middle girder. If we put in a middle girder and alternate the ties, why would there not be an even distribution of load between the outer and middle girders?

I think the author took the shortest and most direct way to reinforce, outside of the possible question of putting in a middle girder, which may have been considered and abandoned for good reasons.

I had occasion to inspect and decide upon a trussed bridge that had been reinforced some years previous by the addition of a middle truss. The existing bridge is what is known as a Post truss. (I suppose you are all familiar with the old Post truss.) This truss had a cast iron top chord, and the engineer reinforced it by putting in a middle truss of greater depth than the outside trusses, and of the Whipple type. The panel points did not come opposite the panel points of the existing trusses. As a matter of fact, the difference in deflection in the trusses made it impossible to form any close determination of the distribution stresses in the three trusses, and after this bridge passed under my charge I replaced it with a new one.

I would ask the author if, outside of the transverse bracing in the plane of the old posts, there was any other transverse bracing than the inclined brace under the plate girders?

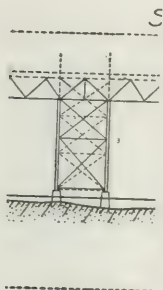
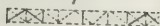
Mr. Curtis: You mean vertical bracing, I suppose. There was no bracing carrying the transverse stresses down to the ground other than that as outlined.

Mr. Stern: There seems to be a general tendency on the part of a designer to reinforce, in most instances. In the majority of cases it would probably be more economical, not only in the long run but in the immediate future, to take out a span. I do not assume that this particular bridge comes under that category, but the subject is a large one, and when I called on Mr. Finley I had hoped he would take up the whole general proposition of reinforcing or replacing, a question in which we are all much interested.

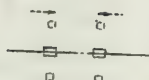
Mr. Finley: The general subject has been very well covered in a paper by John E. Greiner, one-time engineer of bridges for the Baltimore & Ohio Railroad. This article is based on Mr. Greiner's practical experience, and cites the reasons in favor of reinforcing old structures, together with the various conditions to be considered in connection with this work.

As I said before, I know of no engineering problem that requires more intelligent thought, and the exercise of more common sense in the application of the practical to the theoretical, than does the reinforcing of a structure. Some structures have been reinforced (I think I have been guilty of occasionally doing this) which would better have been replaced. On the other hand, we

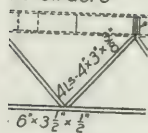
New Hips



'S



Old Girders



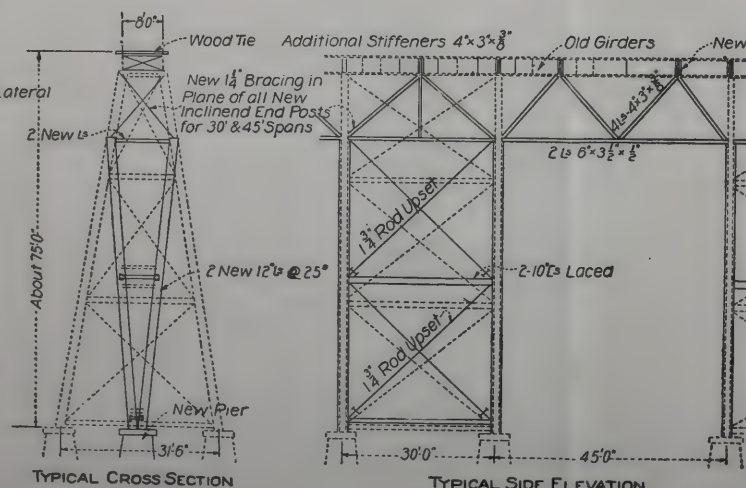
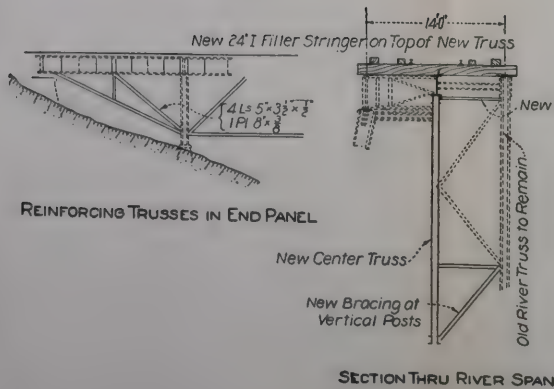
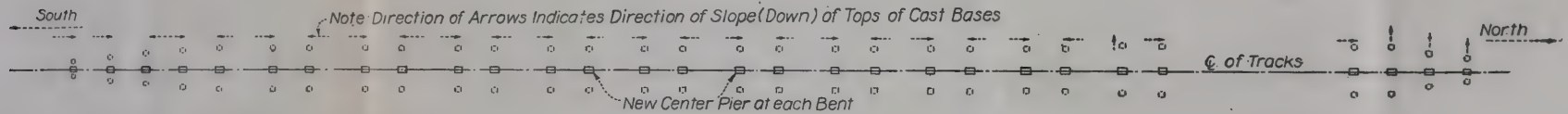
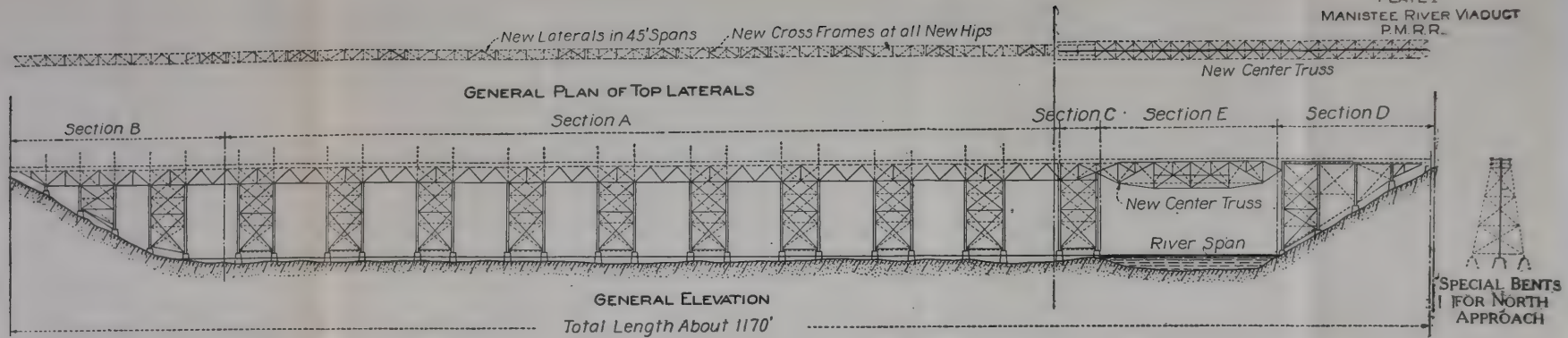
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. 45' 0" -----

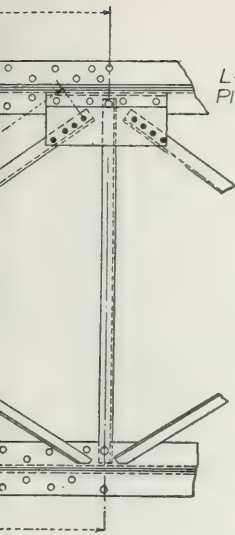
E V A T I O N

962A

PLATE I
MANISTEE RIVER VIADUCT
P.M.R.R.

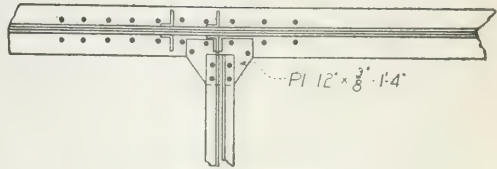


462B



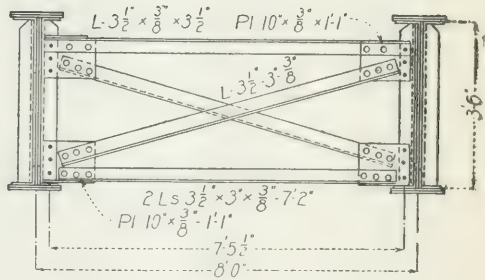
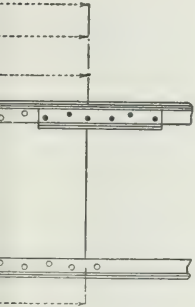
$L-4' \times 4' \times \frac{3}{8} \cdot 2'7''$
Plate $14' \times \frac{3}{8} \cdot 2'7''$

PLATE II
MANISTEE RIVER VIADUCT
P. M. R. R.



$PI 12' \times \frac{3}{8} \cdot 1'4''$

HALF SECTION A-A



$L-3\frac{1}{2}' \times \frac{3}{8} \times 3\frac{1}{2}'$ $PI 10' \times \frac{3}{8} \times 1'1''$

$L-3\frac{1}{2}' \times 3' \times \frac{3}{8}$

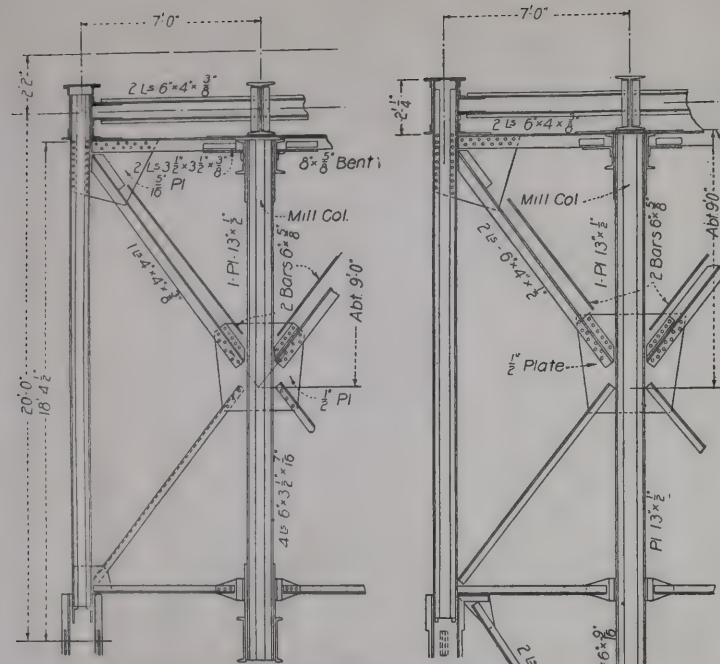
$2 Ls 3\frac{1}{2}' \times 3' \times \frac{3}{8} \cdot 7'2''$
 $PI 10' \times \frac{3}{8} \cdot 1'1''$

$7'5\frac{1}{2}''$
 $8'0''$

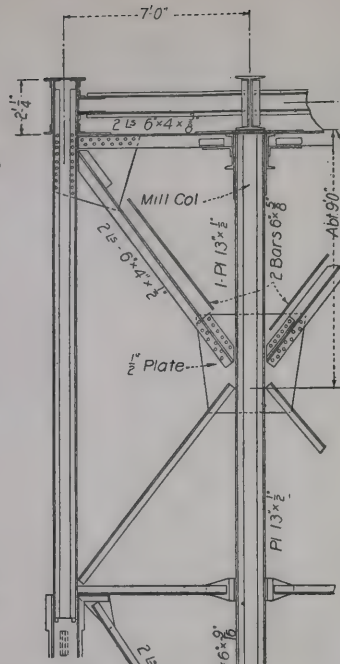
$3'6''$

962c

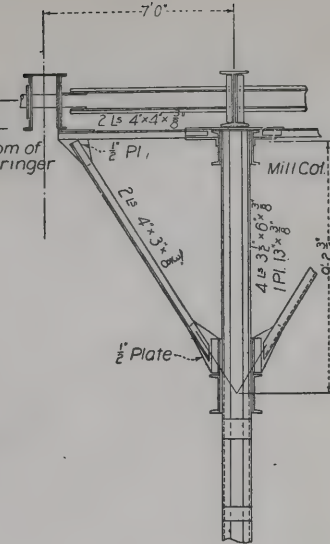
PLATE III
MANISTEE RIVER VIADUCT
P.M.R.R.



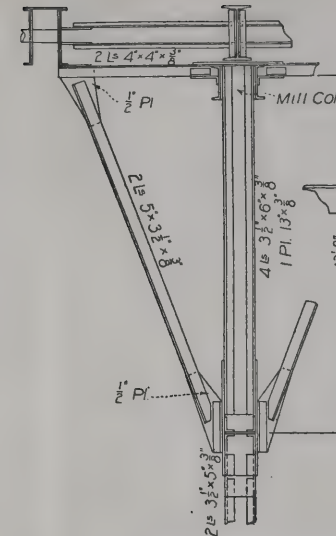
CROSS SECTION U1L1



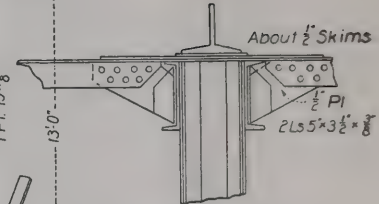
CROSS SECTION U4



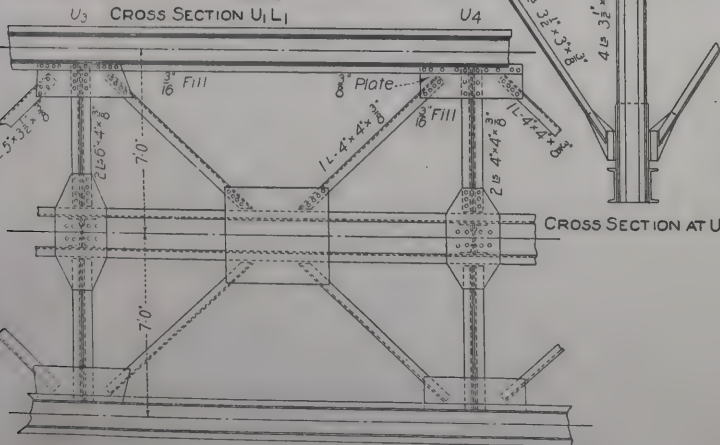
CROSS SECTION AT U2L2



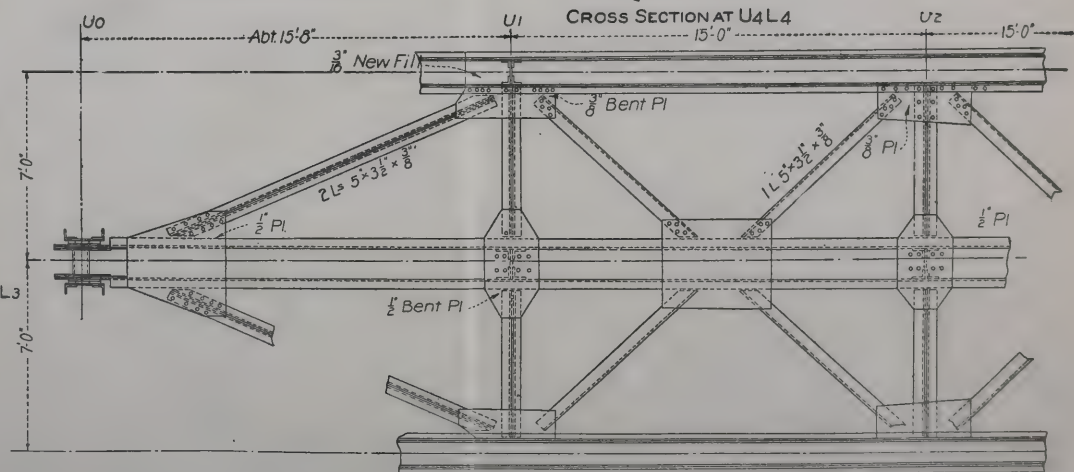
CROSS SECTION AT U4L4



ALTERNATE DETAIL
CONN. OF STRUT TO CHORD
AT U1-3&5-OTHER POINTS SIMILAR



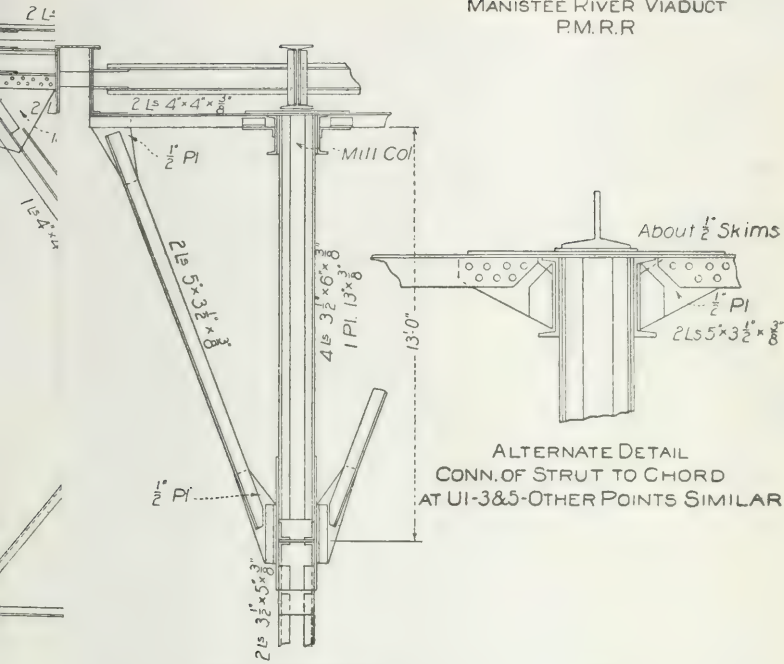
CROSS SECTION AT U3L3



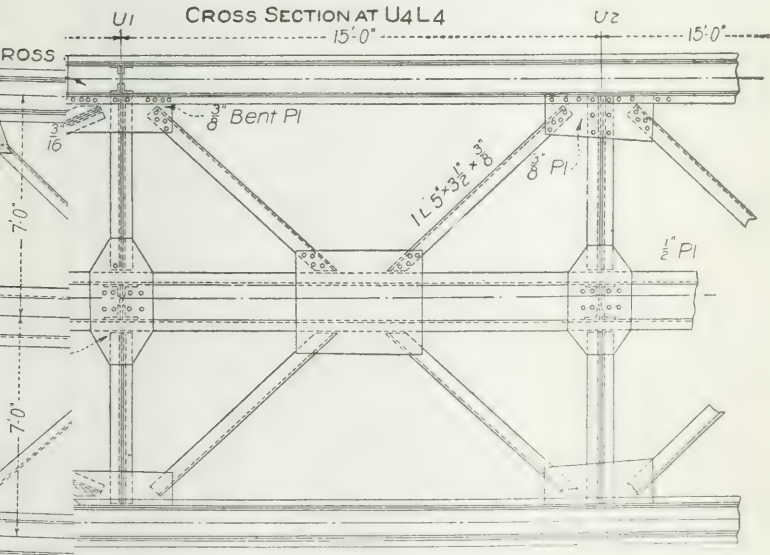
CROSS SECTION AT U0

962c

PLATE III
 MANISTEE RIVER VIADUCT
 P.M.R.R.



ALTERNATE DETAIL
 CONN. OF STRUT TO CHORD
 AT U1-3&5-OTHER POINTS SIMILAR



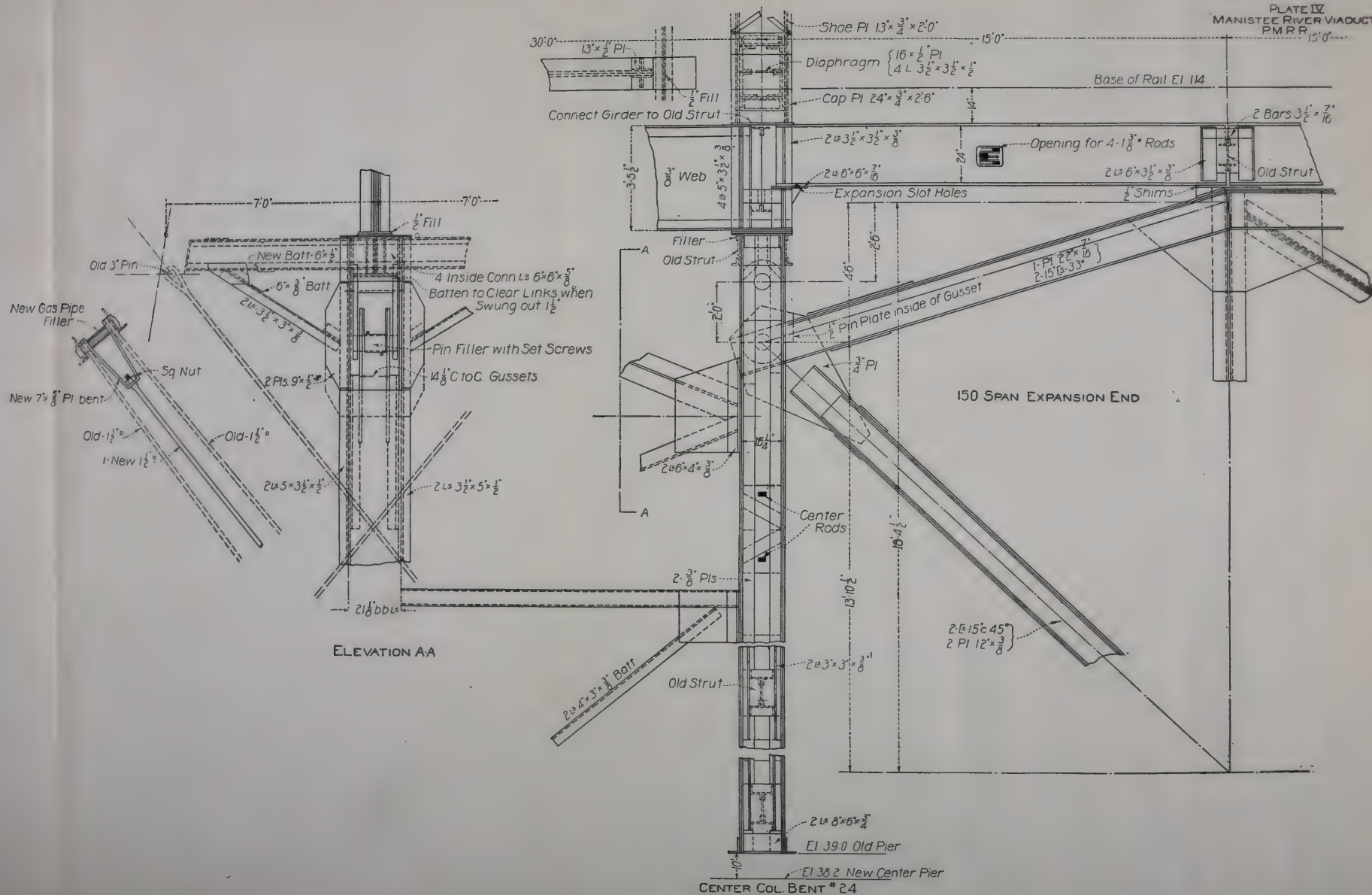
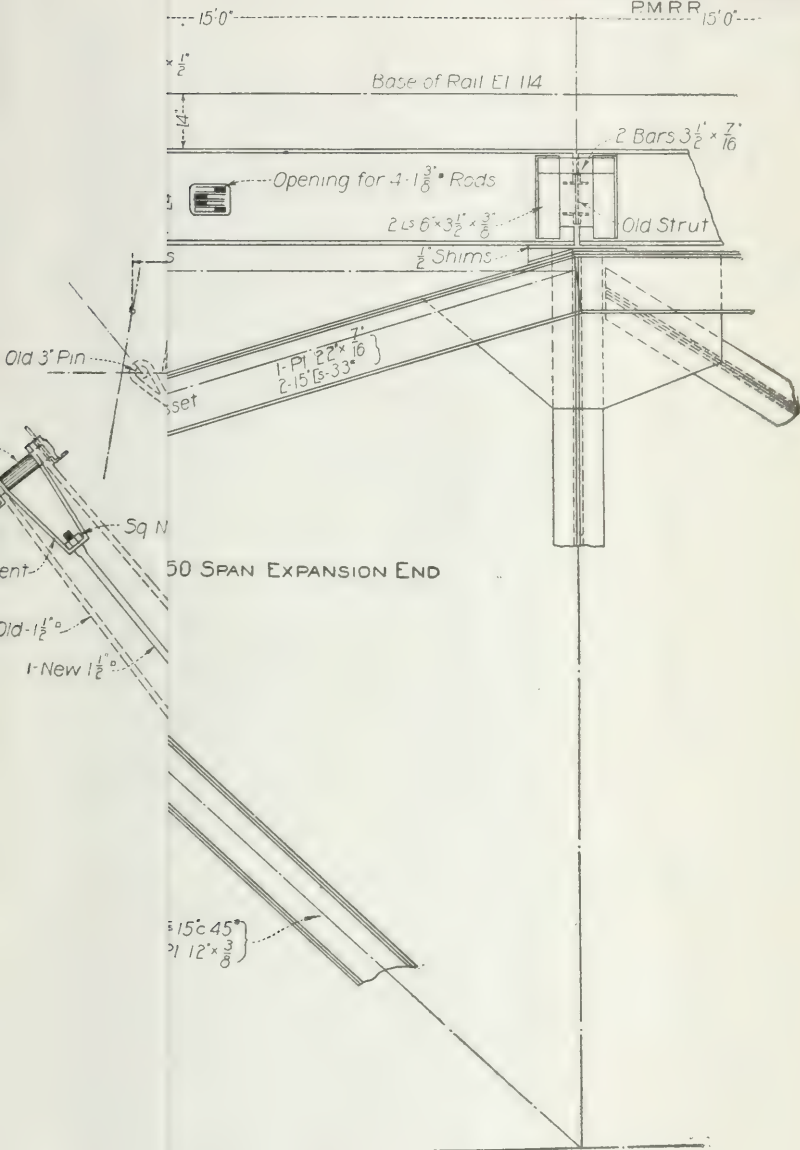
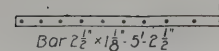
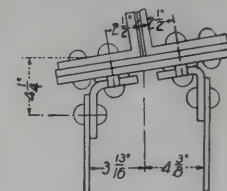


PLATE IV
MANISTEE RIVER VIADUCT
P. M. R. 1510





Fill $7\frac{1}{2} \times \frac{1}{2} - 2 - 0\frac{1}{2}$



VIEW AT A-A

Technical drawing of a steel truss structure, showing two views: a side elevation and a plan view.

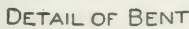
Side Elevation:

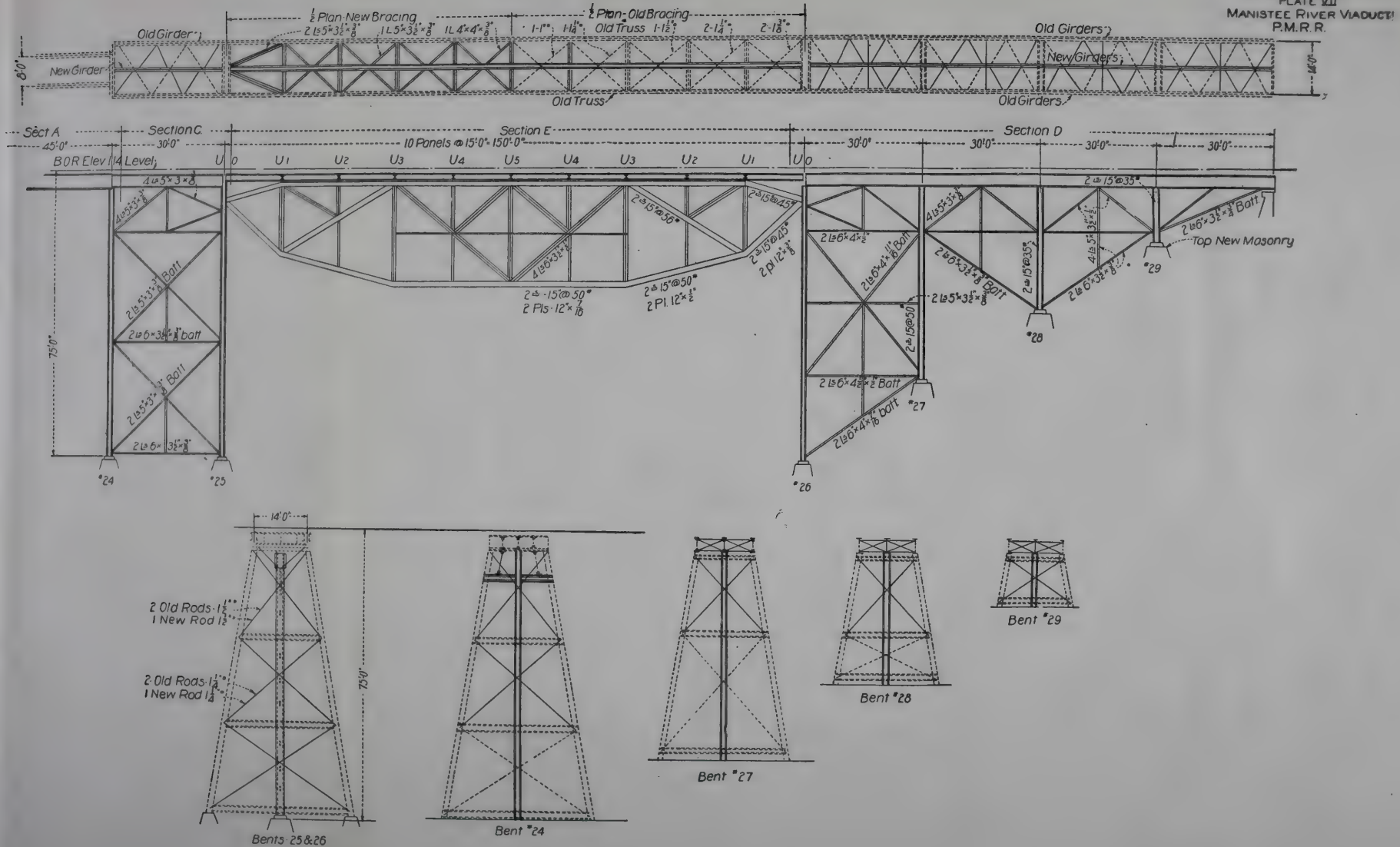
- Top Chord: 9 @ 20" Chan
- Bottom Chord: 2-12" Chan's @ 20"
- Vertical Member: 1L 3" x 3" x 3/8
- Diagonal Member: 6' 1 3/8"

Plan View:

- Top Chord: 2-Chan's 10" @ 20"
- Bottom Chord: 2-12" Chan's @ 20"
- Vertical Member: 1L 3" x 3" x 3/8
- Diagonal Member: 6' 1 3/8"

The drawing includes various dimensions and labels for structural components, such as 3/4" Rod, 8" x 8" x 3/4" L, and 1/4" Rod.





find many structures reinforced, where the reinforcement represented economy over rebuilding.

One problem which must be considered is expediency. This structure of which the author had charge was on the line of a railroad that had not much money to spend; it had to do the best it could with what it had to do with; it had to cut its cloth according to measure; it had to get the very best results out of its available funds. For this reason, I think its problems should be considered in a different manner from that of a railroad that had plenty of money to spend and that had an assured future. For instance, take railroads like any of the big lines running out of Chicago: They may have problems on their main lines where a bridge might be reinforced; yet it might be better economy, owing to the settled condition of things and the surety of traffic, to rebuild it. On the other hand, they might have branch lines on which it would be economy to spend a certain amount in reinforcement to accomplish a certain purpose rather than to spend a greater amount of money in building a new structure.

About sixteen years ago I had occasion to reinforce a bridge across the Root River at Racine. It was a double-intersection lattice deck bridge with a single web top chord, and consisted of a 120 ft. drawbridge and two 120 ft. spans. It was then carrying a gauntleted track, and there was always a question of double-tracking this bridge. There were certain conditions, however, that warranted holding off. It seemed to me a specified sum of money could be spent in reinforcing the structure to carry the traffic. This was done, and the bridge continued in service, with greatly increased loading, for a number of years.

There is one thing that I want to say in regard to specifications. We are inclined to take standard specifications (for instance, like those of the American Railway Engineering Association). I defy even such an expert as my friend Curtis to take those specifications and apply them to the structure that he has just reinforced. Whatever the standard specifications may be, we cannot apply them to the strength of an old bridge, or the reinforcing of an old bridge, without exercising our own experience, knowledge, and common sense as to what ought to be done and what ought not to be done.

Mr. Stern: I heartily concur in Mr. Finley's last remark that we must use our own experience and common sense in the matter of reinforcing. I suppose the paper by Mr. Greiner, referred to, is the one in Bulletin 139, of the American Railway Engineering Association. It is a remarkably fine paper, one of the best on the subject that was ever published. Mr. Finley once told me about a truss which Mr. Greiner designed some years ago. It was made out of old T rails, and in the hands of an experienced designer like Mr. Greiner, could be used to advantage and it was very economical. Mr. Greiner patented it, for just one reason, namely, in

making use of it the inexperienced designer would be likely to get into trouble with it.

I think the article referred to comes under the same category. It was very much admired by men who were not experienced and not capable of taking into consideration all the conditions, and for that reason I think the article has done some harm in the country. It would have been a good thing if Mr. Greiner had patented that paper so that it could be applied only by designers experienced in that kind of work. I personally have been up against that question in the last two or three months, where I recommended that some bridges be taken out.

I was much impressed also with the idea that the author brought out (although he did not definitely state it).—the old principle that construction must not only be safe, but it must look safe. He has called attention to the heavy appearance of the new structure and to the fact that it looks safe. As has often been stated, it is very important that the designing and the carrying out of designs be in the hands of experienced men, who are visual engineers, and who, when they see a plan can tell practically whether or not it is safe.

The author has given a good deal of attention to the matter of bracing, and in designing old structures it is the one matter that must be considered almost above all others, because the old structure is rickety and shaky and, as is often said, liable to shake itself to pieces, although that is somewhat of an exaggeration. The adventitious brace that is put in is one of the things that conduces very strongly to the safety of the structure.

The fact which the author continually iterates, that there was no interruption to traffic, greatly impressed me. That is the one thing we almost always assume, for if the reinforcing of a certain line requires that the line be shut off while the work is in progress, we will not be allowed to reinforce it. It is the one thing all railroads must work out for themselves, that is, have their engineers work it out, when they make any design for reinforcing. It is remarkable how busy the operating department is as soon as there is any work to be done on the line, and it has been of advantage to engineers, because it has made them exercise their ingenuity.

It is a very good thing for the Society to have a paper of this kind, one that does not go into the mathematics of the problem, but does go into the practical details.

The matter is now open for general discussion by the Society. The chair will call for volunteers.

M. D. Kolyn: It seems to me the stresses in that truss could be determined, or at least worked out, by a method and without any difficult equations, especially in the shorter truss where we have the support at the center. Two diagonal members will contract and there will be a deflection of the beam, so I think there ought to be a solution of the stresses in that—a mathematical solution.

Mr. Stern: Is not that practically begging the question? In other words, you first put in the members and see what they are stretched to. That is hardly the thing we want to do. It seems to me that Mr. Finley's suggestion is better, that we figure what stress we want to put in the transverse girders which we are going to put on as a top chord under Mr. Curtis' scheme, and find what deflection is brought about in carrying that stress; then assume that the other must take that difference in stress so as to keep the deflection within that limit.

H. C. Loud: Were the holes put in before the columns were erected, or afterwards?

Mr. Curtis: In general, they used the new column as a templet and bored the holes. Just to what extent that idea was carried out I am not prepared to state. I had hoped Mr. Ross, who had charge of the erection, would be here. I visited the site only a few times during the process of erection, but that is what they were doing when I was there and that was the general idea. The newly punched metal was used for the templet. Enough holes were drilled so that the new piece could be fastened in place, and then they drilled through and through to make the connection.

Mr. Kolyn: I would like to ask about the phosphorus. The test of sample A shows 0.405%. Did you ever make any further test to see how much phosphorus you had?

Mr. Curtis: No, we did not. On the second series, only physical tests were made.

Mr. Finley: I would ask if the old columns under the new loading were badly over-stressed?

Mr. Curtis: They were not at all over-stressed under the new loading.

Mr. Finley: I mean were the old columns too weak under the proposed new loading?

Mr. Curtis: Yes, and they would have to be reinforced.

Mr. Finley: In the truss span 14 ft. centers, was there any floor system?

Mr. Curtis: No, the track was on heavy ties.

Mr. Finley: Are you still sure you have the same deflection?

Mr. Curtis: That was a point very seriously discussed, and we finally concluded, after looking at the matter from all sides, that we would shut our eyes to some of the theory.

Mr. Finley: Why didn't you use short ties, and alternate them?

Mr. Curtis: That idea never occurred to me. I do not know whether any of the people at Milwaukee thought of it or not.

Mr. Stern: What was your object in making the center truss deeper on the river span, and was it necessary to do that? It made more difficult details.

Mr. Curtis: We had practically twice the load that we have on the outside trusses and the trusses figured out more economically, that is all.

Mr. Finley: How about your lateral system?

Mr. Curtis: We had a new system. The struts were inclined from the side trusses down to the other trusses and we had very heavy cross frames.

Mr. Finley: Wouldn't you have obtained better design and better stiffness if you had made the new truss the same depth as the older trusses?

Mr. Curtis: Can you answer that, Mr. Pearson?

C. M. Pearson: I do not know why they did not use the same depth except for economical design of the new truss taken by itself. They figured on the new truss carrying over to the old trusses by means of the new cross frames.

The old truss was 20 ft. deep and the new one about 30 ft., I think. Such a long time has elapsed since I worked on it I have forgotten the figures.

Mr. Warder: How long was this job in construction?

Mr. Curtis: The contract was let in October and we started the foundations about the first of November; we began to erect steel about Christmas time, of the same year. The new schedule went into effect June 15th, the following year. We were held up at least six weeks on account of foundation trouble and high water. We had our steel lying around there buried in the snow.

E. N. Layfield, M. W. S. E.: I was going to make the same criticism that Mr. Finley did in calling that construction a truss for the short span; that is, for the short span only. It seems to me that it is fair for the author to call the longer one a truss, with the girder for the top chord, that is, two middle quarters of the girder. This is not a very important matter, perhaps, but inasmuch as the author states that it is the fundamental principle on which this reconstruction is done, perhaps he would like to change that part of it.

Mr. Curtis: That and several other features about the reconstruction were largely indeterminate. It was figured throughout as a truss. The general design was planned in my office at Detroit, and when the business was secured the plans were transferred to our engineering department at Milwaukee to detail and complete. I practically dropped the matter there, which accounts for my ignorance of some of these matters of detail. My original idea was to have the construction a truss, and while I have not followed through all of the mathematics that took place in Milwaukee, I am correct, I believe, in my understanding that it was carried out as a truss. It seems to me that while the problem could be analyzed as Mr. Finley has suggested, and it could also be analyzed as one of the other gentlemen suggested, the final result will, as Mr. Finley also suggested, satisfy all three of the solutions. They are all more or less indeterminate. If you put it the way Mr. Finley says and if it chooses to act as a truss, you cannot prevent it from acting as a truss. If it is figured as we figured it, and the old girder is not sufficiently supported but what it acts slightly as a girder under

deflection, why, my theory will not prevent it. And as long as it will figure for any system, I think anyone is at liberty to figure it any way he chooses.

Mr. Stern: I would ask Mr. Finley, if the diagonal members were so placed that their center lines intersected at the center line of the girder, would not that make a proper top chord action?

Mr. Finley: It would, of course, theoretically make a top chord action, but that would be unnecessary and I think it would not be wise, because the plate girder is so much more than is necessary for a top chord of the truss that the only sensible thing to do is to do as they evidently did,—consider the bottom flange of the plate girder the top chord of the truss.

Mr. Layfield: It seems very clear to me, that the two middle quarters of the long span are really the top chord of the truss. They are in compression and have all the characteristics of a truss; but the two end quarters of the long span and both halves of the short span are not in compression as far as I can see from the illustrations or the presentation of the paper. In the short span, as I look at it, there is nothing but an A frame that is supporting the middle of the girder, as Mr. Finley said. Of course, the same thing applies to the end quarters of the long span, but for the two middle quarters of the long span the girder must act as the top chord or there would be nothing to keep the two panel points apart.

Mr. Finley: The short or tower span is merely what is called the King post truss with the floor carried on the top.

Mr. Curtis: Mr. Finley raised a point about the foundations.

Mr. Finley: What is the span?

Mr. Curtis: The span is about 30 ft.

We had the old plans and figured that there were not enough piles there to support the new loading and we had to provide more of them. It was impracticable to get more piles around the old ones, so we put in new concrete piles, as that seemed to be the only solution.

Mr. Finley: Did you have as much confidence in the piles under those old foundations as you had in the trusses?

Mr. Curtis: Yes. There was no criticism of the old foundations except that there were not enough piles.

Mr. Finley: What would be the load on those piles in tons per pile, under the new condition, if all the load were carried on the old pedestal?

Mr. Curtis: I do not remember.

Mr. Finley: Was that center pedestal expensive?

Mr. Curtis: The foundations cost about \$9,000; the job as a whole cost \$43,000, a little less than a quarter of the cost of the reinforcing.

The other question Mr. Finley raised in regard to the action of the truss, has been pretty well discussed. While I remarked in the paper that the old girder acted as a top chord for the new

truss, I did not qualify that as closely as I might have done. As a matter of fact, only the lower half of the middle portion of the bottom chord of the girder acts as the top chord of the newly formed truss. In the paper I think I remarked that the short span was similarly treated. That was misleading. It was similarly treated in the matter of drafting because we put in similarly arranged members; but in the matter of theory there was no new truss action at all there, and I will correct that statement when the paper appears in the Journal.

Mr. Finley: I do not want the author to think that my criticism of the plan was captious; but there is this thing to say about it: Without any question the method of reinforcing the structure that would interfere least with traffic was adopted, and that is one of the big problems on a railroad. At times we must sacrifice many things in order to execute the work in such a way that it does not interfere with the traffic. A railroad is a transportation proposition, and engineering and the building of bridges and the reinforcing of them are incidental thereto. The best engineering skill is used to devise a method within reasonable limits that will interfere the least with the traffic, and I think Mr. Curtis was very successful indeed in this particular.

Mr. Curtis: I am glad Mr. Finley mentioned the non-interference of traffic, because, as a matter of fact, I believe that proposition sold the job. The fact that we were there for six months without stopping or holding up any regular trains appealed very strongly to the management of the road. We sometimes held up "wild" trains, but none of the regular trains. Of course, the traffic was not very heavy up there. I think we had six passenger trains per day, three each way, and four regular freight trains.

Mr. Stern: The Society is indebted to Mr. Curtis for coming to Chicago from Detroit and giving us this very interesting paper, and on behalf of the Society I desire to thank him.

COST SYSTEMS IN ELECTRICAL CONTRACTING

LEO DOLKART, ASSOC. A. I. E. E.

Presented Before a Joint Meeting, Electrical Section, W. S. E., and Chicago Section, A. I. E. E., May 26, 1913.

Hitherto it has been difficult to obtain data on costs and systems in contracting. This is especially true of the electrical contracting business. Contractors as a general rule are reticent in regard to the manner or method by which they arrive at their results. It is a fact, of course, that many contractors really have no method. The question with them is how close they can guess. At any rate there is a feeling among some contractors that if they happen to lose on one job the loss will be made up on the next one, since to them estimating represents a guessing contest. Of course, such contractors learn to their sorrow of the laws governing probability and chance. A feeling exists, too, that if one contractor devises some good system or an improvement in the method of doing business, there is a desire to "lie low"—to keep it from the "other fellow." It does not require much reasoning to see that such methods, as well as being out of date, are not productive of the best results. Coöperation and interchange of ideas between contractors will do much to uplift the profession and at the same time be of material benefit to the members thereof.

Estimating is, at its best, a very indefinite or indeterminate process, owing to the fact that so many variables make up the whole. Several of these, however, follow certain rules and may be more or less easily determined. In electrical contracting the material to be used on any particular job can be estimated to within a small percentage of that actually required. With the labor, it is an entirely different matter. Some of the variables to be considered in estimating the labor on any particular job are:

Season of the year the job is to be installed.

Rapidity of work of wireman A.

Rapidity of work of wireman B.

Rapidity of work of wiremen A and B when working together.

Section of state or country where job is to be installed.

It is hardly necessary to call attention to the fact that some work can be done more rapidly in cool weather than in warm weather, and vice versa. It is also true that if wiremen A and B are put to work together on one job, the net result will more often be less than the sum of the net results of both A and B, were the two working separately. The net result may be also very different from that obtained by putting A and C or B and C together. The most economical combination can be determined only by trial.

That the section of the country where the job is being installed bears a certain relation to the rapidity with which the work will be completed is too self-evident a fact to need further elucidation.

One would at first imagine that with all these different items determined upon and the total material and labor estimated, it is an

easy matter to arrive at the total cost of the job. Adding to the total the per cent of profit would or should give the total amount of the bid. For illustration we will suppose a job X:

Material cost	\$150.00
Labor cost	100.00
Total	\$250.00
15% profit	37.50
Bid	\$287.50

From the above it would appear that the job should net a very satisfactory profit of \$37.50. Many contractors actually assume that \$250.00 represents their actual cost on the above job. Really, however, such a cost system does not represent the true and accurate state of affairs. Expenses such as rent, telephone, light and power, office help, freight, etc., have not been considered. All such expenses coincident to the pursuit of the business make up what is termed the overhead expense.

It has been the practice, hitherto, of contractors taking care of the overhead to obtain the total overhead expense for the year, and, by dividing this sum by the total amount of business done during the year, obtain what is termed the percentage of overhead. That is, if the total amount of business for the year was \$40,000, and the expenses for the year amounted to \$8,000, the overhead would be 20%. At first glance this would appear rather large for this amount of business, but actual facts as compiled from information supplied by contractors throughout the United States prove this percentage to be very low.* As a matter of fact, for this amount of business it would be nearer 22%. The percentage of overhead bears an inverse ratio to the amount of business done, and for a total year's business of less than \$1,000 it amounts to about 45%.

Taking the same example as considered in job X and applying the above rules, the cost would be as follows:

Material cost	\$150.00
Labor cost	100.00
Total	\$250.00
20% overhead	50.00
Actual cost	\$300.00
15% profit	45.00
Bid	\$345.00

It will be readily seen from the above that had the contractor taken the job for \$287.50 he would not only not make any profit but would be an actual loser of about \$12.50.

*The National Electrical Contractor, Vol. 2, No. 2, Dec., 1911.

It is, of course, self-evident that the first method of figuring is entirely wrong. It is surprising that so many contractors do actually pursue such antiquated methods and are wondering why business seems so unprofitable.

It is the aim of this article to prove that even the second method of figuring is wrong, in that the manner of obtaining the overhead expense is not strictly in accordance with the actual state of affairs. This can be readily seen from the following illustrations. Take two jobs whose total costs equal the same but with varying labor and material items:

Job A.	Job B.
Material cost .....\$100.00	Material cost .....\$150.00
Labor cost 150.00	Labor cost 100.00
Total .....\$250.00	Total .....\$250.00

It is evident, of course, that job A will take one and a half times as long to complete as job B, but will, with the ordinary method of figuring, bear exactly the same percentage of overhead. If one stops to consider the components that comprise the "total overhead expense" one can readily see that most of these elements, rent, salary, telephone, insurance, etc., bear a certain relation to time. It is self-evident, therefore, that the total sum of these should also be proportional to time. In other words, if job A took one and a half months to complete, it would cost the contractor just one and a half times as much in labor overhead expense as job B, which took only one month to complete. Consequently overhead expense being proportional to the time element is proportional to the amount of labor, conveniently called "man hours."

It is apparent also that the cost of handling a job that takes a good deal of material is more than one that takes less material. It would appear, therefore, that in order to be just to the material and labor items, it would be necessary to divide the total overhead expense into two separate parts, one proportional to labor and the other to material. This the writer has applied to actual work and found to be very satisfactory.

The cost of doing business per "man hour" can be easily determined. In order to do this it is necessary to divide the total cost of doing business into two sets of expenses as shown below:

LABOR EXPENSE.

Office rent.
Office salaries.
Telephone and telegraph.
Light and power.
Liability insurance.
Office supplies.
Depreciation of furniture.
Depreciation of tools.
Maintenance of automobile.
Depreciation of automobile.

MATERIAL EXPENSE.

Store room rent.
Stock clerk's salary.
Freight and hauling.
Fire insurance.
Stock room supplies.
Depreciation of furniture.
Maintenance of wagon.
Depreciation of wagon.

By dividing the total labor expense for the year by the total amount of labor hours, the overhead per "man hour" can be easily obtained. Dividing the total material expense for the year by the total amount of material handled will give the percentage of overhead for material.

Referring back to our two jobs and correcting the overhead we will find the following net results:

Job A.		Job B.	
Material cost	\$100.00	Material cost	\$150.00
Material overhead,		Material overhead,	
5%	5.00	5%	7.50
Labor cost, 300 hrs.	150.00	Labor cost, 200 hrs.	100.00
Labor overhead, 25c	75.00	Labor overhead, 25c	50.00
Total cost	\$330.00	Total cost	\$307.50
15% profit	49.50	15% profit	46.13
Bid	\$379.50	Bid	\$353.63

Comparing these figures with our previous computations, it will be readily seen that if job A were taken for \$345.00 it would not have proven very profitable. On job B the profit would be slightly greater than the original bid allowed.

The division of the overhead expenses as outlined above takes care of practically all expenses incidental to this line of business. There may be two or three items which it may be deemed advisable to also include in the overhead, such as taxes, advertising, and bad accounts. The latter, particularly, should be such a small item with an electrical contracting business that it may be best to charge it to the profit and loss column. In some localities the item of advertising may call for very heavy expenditures. In such cases the total expense should be divided and the material and labor expenses be made to take the *pro rata* shares.

Both the labor and material expenses may be readily shown graphically month by month. The writer finds it very convenient to plot these expense curves for reference. At a glance these will indicate the "pulse" of the business, for with an increase of business the overhead falls and rises again with a slump in the business.

The curves in Figs. 1 and 2 illustrate graphically some of the expenses previously indicated. Figure 1 shows some of the larger expenses. It may be desirable to combine the two expenses indicated by the general office salaries and clerks' salaries. In this particular instance, however, it was thought advisable to keep the clerks' salaries separate from those of the officers of the company and the engineer. Figure 2 shows the overhead per man-hour curve and one drawn to indicate the general average for the entire year. One can at once see how the cost per man-hour decreases with the increase in the amount of business done. This, of course, bears out actual conditions when work is plentiful in the summer

and fall months. With a decrease in business the overhead increases, due to the fact that the actual expenses are not proportional to the amount of exact business transacted. That is, if during the summer months the business increases 100% over that done during the winter, the expense of doing business will not fall in the same

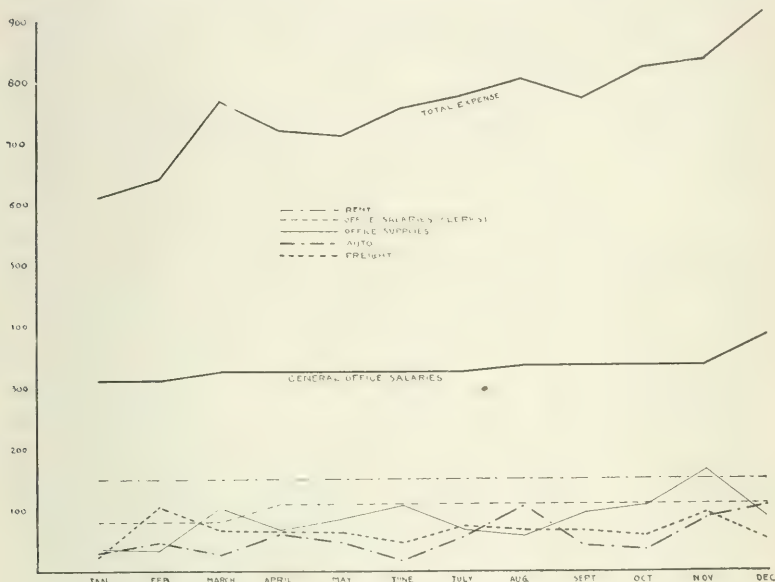


Fig. 1.

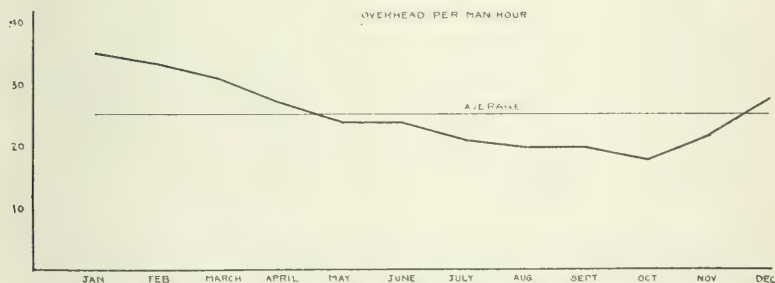


Fig. 2.

ratio. Actual facts bear out this statement since the expenses month by month for any particular business do not greatly vary.

It is convenient, for record, to plot each expense month by month. At the end of the year a study of these will be of material assistance to any business in deciding upon policies to be pursued for the ensuing year.

DISCUSSION.

R. H. Rice, M. W. S. E.: I regret that Mr. Dolkart is not here this evening, and also that he has limited himself to such a small field. I had hoped he would take a broad view of the question and open up some of the points that would draw out discussion. In the discussion we need not confine ourselves to the figures given, but the general questions raised in the paper are questions of importance. Probably each one here has some point of view which refers especially to his own business.

The two chief points which I noticed in the paper are: First, the statement of the unreliability of estimates, and second, the relative amount of the overhead expense and the cost of the entire piece of work.

In regard to the first point, I think it is not quite fair to state that estimates are necessarily unreliable. Estimates cannot naturally, in general, come to the exact cost, because there are too many elements of uncertainty, too many elements that cannot be foreseen. The second point is a very important question. In general, as the author states, I think most engineers are inclined to underestimate the overhead expense. When we begin to count up the overhead, it becomes a large figure and continually increases, and we begin to doubt our own figures and our own judgment, and the tendency is to trim it down,—to be a little conservative. The general result of that tendency is, we trim it down too much and occasionally have some difficulty in explaining why our estimate does not correspond with the facts when the work is completed.

The things that I am most familiar with are the so-called traction settlement ordinances of 1907. In those ordinances and in the valuations which preceded them and some valuations which have followed, it has been the custom to allow certain percentages which have become more or less fixed. On straight engineering work the allowance is 15%; that is, the valuation is made of the actual value of the physical property in place, including the material and labor. To this is added 15% for engineering and for organization, or the carrying of the engineering organization. After all these expenses (the cost to reproduce as it is generally called) are added up, we get a total figure which is the so-called actual cost of the work, or of the physical property. Then to this are added all such overhead expenses as general salaries, office expenses, rent, legal expenses, and brokerage for the cost of raising money. That makes, say, a 20% general increase over the actual cost of physical property. The same ordinances allow the railway companies 5% interest on their capitalization, so that has a tendency to increase the overhead somewhat more. If you will take the actual cost of any piece of work that is done and consider the real, legitimate overhead expense, you will be astounded, in general, by the size of it. It is probable that the overhead expense, so-called, of a business which requires a large force of salesmen will run higher than the ordinary engineering work. I have no definite idea what it would

cost in overhead expense to run an automobile business, but it would probably be 50%, because the nature of the business is such that a large part of the expense has to do with the introduction to the public of the material which is for sale.

There is one other question mentioned by the author which I would like to have some one discuss, and that is the subject of depreciation. The author simply mentioned it, and I am disappointed that he did not go into the matter more fully.

C. A. Keller, M. W. S. E.: I do not care to discuss the general subject of depreciation, but would like to give my ideas of what the cost-keeping system of an electrical contracting business should consist. It is evident that Mr. Dolkart's paper treats only of ordinary house-wiring contracting; nevertheless, I was disappointed that he did not describe the cost-keeping system.

To my mind the duties of a cost department should be as follows:

1. To prepare all estimates, basing them on units derived from some previous job executed under similar conditions.
2. To keep a cost book, arranging the items in the order of some standard code, and obtaining the data from the weekly time and material reports.
3. To prepare weekly or monthly statements of the cost of each job, comparing the probable final cost determined from the unit cost of the job to date with the original estimate. From these figures the estimated net profit from the job may be determined each week and gives the contractor a system whereby he can determine how the job will terminate.
4. To prepare weekly unit costs of the important portions of the job, comparing them with the unit costs of the previous week and those used in the estimate.
5. To keep a complete record of contracts and progress of the sub-contractors.
6. To keep a complete record of changes, including additions and deductions on the contract.

The personnel for such a cost department will depend entirely upon the size of the business. For small contractors, an estimator who should also be a draftsman, and a timekeeper, would probably be sufficient. For the large contractors, this department would require a considerably larger force, including several estimators and clerks.

Mr. Rice: Mr. Keller's remarks suggest to me two firms which I happen to know. The first is a large firm, doing a large amount of engineering work. For each piece of work done, a careful graphic record of each kind of work is kept; for instance, foundation work, construction of buildings, construction equipment, and such miscellaneous construction work as erection of cables, and pole lines. Cost data are kept of the actual labor cost and the material actually used, so that it is known within a day exactly how much has been put into the work,—just how much the work represents

in value which the firm will receive for it. So far as I know, that firm has never lost anything on contracts, because it knows exactly what it is doing all the time.

The other company I have in mind is very far removed from the one first mentioned. A man runs a small business and at the end of the month his bookkeeper foots up the debits and credits, and if the owner comes out short, he will say, "Well, I don't know just where I lost it." But he is short and therefore he must have lost money somewhere. If he comes out ahead he congratulates himself and thinks he is making money. That is an actual case, and the man, I suppose, never will get anywhere in business.

There is very little data, in actual figures, at the present time, on the subject of depreciation, which the average man can use. Quite recently a large electric railway association,—the American Electric Railway Engineering Association,—has begun to collect data, through one of its committees, on the subject of the physical life of railway properties, for the purpose of determining the physical life and thereby the rate of depreciation that should be allowed for various pieces of property. If one happens to get into that subject he will probably find very little that will apply to his particular case.

To mention the traction ordinances once more, an effort has been made to recognize that principle by setting up a fund which is 8% of the gross receipts, to provide for renewals. The question at once arises whether any given amount of money set aside is sufficient to secure the end for which it was set aside. It becomes a question to determine, then, whether this 8% is sufficient. To do that, one needs to know how rapidly each piece of his property deteriorates each year. To realize that, he must know something in regard to the life of his property. If he is doing business on a proper basis he will provide, year by year, a certain fund which will be set aside and kept for the purpose of having available, when it is needed, a sum of money with which to buy a new piece of apparatus to replace the one which is worn out. That is the thing which is becoming more or less urgent in all of our engineering work. I wish we might have some opinions on that subject.

John A. Wickum: From my experience, covering a period of fifteen years here in Chicago, this paper seems to hit the nail on the head exactly. I have been one of these long-range guessers myself. Sometimes I hit the mark but I often missed it. To arrive at a system of compiling figures and becoming accurate in estimating on electrical work really is a mathematical proposition and requires a good business head and many years of experience. I tried various systems of bookkeeping and tried to count up every nail and leather head and charge it to the various jobs, yet I found when I came to summarize and balance up at the end of the year I had made numerous mistakes somewhere. To count up the mistakes in one job is almost out of the question. They have to be distributed over the various jobs. They may amount to hundreds of dollars and

possibly run into thousands, but the discrepancies remain somewhere. It is hard to deal with this feature unless one is educated to a system of accurate bookkeeping that eliminates all this on an overhead basis of figuring. I think the contractors in the National Electrical Contractors' Association have arrived at a system about as closely as it is possible to arrive,—a system whereby we can, at any stage of the job, find out exactly where we stand, provided we know the cost of our material and the amount of time; the credits and so on will come afterwards. But we can get very close to the actual cost of the job and know how we are progressing at any stage of the game. Unless such a method is used (which, of course, incurs an expense all the time and which the contractor has got to figure in) one is simply guessing all the time.

J. H. Warder (Secretary): I would like to ask a question in regard to this question of depreciation. Take an electric generator, which we will assume has a ten-year life. Do you assume a depreciation of an equal sum for every one of the ten years and at the expiration of the ten years assume that you have wiped out the cost; or is there a variation between the depreciation the first year from the second and then the third and so on? In other words, is that line of depreciation a straight line or is it a curved line with a less depreciation in the early years and a greater rate of depreciation in the later years,—or conversely?

Mr. Rice: The question Mr. Warder has asked practically opens up the whole subject. I would answer, briefly, that it depends on the purpose for which one is depreciating. The actual value of a given piece of apparatus lessens according to a straight-line rate, that is, equal amounts every year, if one is considering its use. In other words, a rotary converter is worth so much today, and if it has a life, we will say, of fifteen years, it will depreciate $6\frac{2}{3}\%$ each year, as near as we can determine. If, however, we wish to consider that depreciation from the point of view of what we will be able to realize from it at a sale, it would not be safe to consider its depreciation in that manner, because, as soon as a piece of apparatus is placed in service and has been used even a few months it becomes second-hand and depreciates greatly,—so that at the end of the first year it is worth less, to sell, than $93\frac{1}{3}\%$ of its cost new, although it may be worth that much in future use.

There is another phase of the question,—namely, that always when we are speaking of depreciation there is uncertainty as to whether we are speaking of a depreciation *rate* or a depreciation *fund*. If we are speaking of the rate of deterioration of a piece of property, that is a depreciation rate. If we are speaking of the way in which we must build up a fund to replace that piece of apparatus when it is worn out, that is, from the accounting point of view, a depreciation fund. Personally, I think it has been the custom to look upon depreciation of the physical property as being on a straight-line basis. But by the setting up of a depreciation fund to replace that property when worn out, on a sinking fund

basis (that is, a certain amount put into a fund and reserved, drawing interest to the end of the life of that piece of property, as estimated, another amount set aside the second year and drawing its interest to the end of the life, and so on), then at the end of the estimated life we will have the same amount of money that we originally paid for the piece of apparatus, and we will have paid into the fund actually less than the original cost of the apparatus, because of the interest which has accumulated. The first is the physical depreciation. The second is the rate upon which we set aside the money for our depreciation fund. One is an engineering proposition; the other is really an accounting proposition.

Mr. Warder: Do you take into consideration the possible salvage value at the expiration of the life of the property?

Mr. Rice: Yes, the cost new of the property is estimated or known. Its salvage value is known or estimated. The salvage value may be a scrap value or it may be a greater value than scrap, due to the fact that while the apparatus has ceased to be useful to one, it may be useful to another, and can be sold. Deducting the salvage value from the cost new, the difference is what we may call the wearing value, and the rate of depreciation is applied on the wearing value. For illustration, suppose we have a piece of apparatus that costs \$1,000, and has an estimated life of ten years. This means that if it has no scrap value, no salvage value, it will depreciate 10% a year, and if we set aside according to a straight-line basis, we will set aside \$100.00 every year for ten years, when we will have the cost of the apparatus. If we set aside on a sinking-fund basis, we will set aside (I do not know what the figure would be), we will say \$95.00 per year, making a total of \$950.00 that we put in, and the other \$50.00 would be the accumulated interest on those successive annual payments. If, however, that piece of property has a salvage value of 10%, then we must set up a fund which will accumulate \$900.00 at the end of ten years. We can set it aside \$90.00 per year or possibly \$85.00 per year on a sinking-fund basis. When we get to the end of ten years we will have \$900.00 in our fund, plus \$100.00, the salvage, or \$1,000 to buy a new piece of apparatus.

That simple process is complicated by several things. Of course, the most obvious complication is that we may have made an error in our estimate of life. The second thing is that the piece of property may become obsolete, due to the fact that some better and more efficient device has been introduced, in which case we may have gone on five years and accumulated \$500.00 and then have to scrap that piece of apparatus. Then we are \$500.00 short, which we have simply got to charge up to experience.

H. S. Pardoe: It seems to me the value of an estimate or the value of an engineering report is quite well measured by the agreement between two independent competing estimators or engineers, and when there is a difference in an estimate or in an appraisal of some \$40,000,000 out of \$90,000,000 or \$100,000,000 (referring to a

recent appraisal of our elevated railways), it shows that there is something the matter with the estimating business. I am concerned with little about depreciation and kindred subjects, but the results that appraisers and estimators obtain show that the art is in a state that is far from being exact. One of the reasons which may contribute towards that condition is that much of the engineer's energy is expended upon more or less inconsequential items as compared to the big items.

But I cannot agree with the statement that the estimating for the contracting business is unreliable and entirely guesswork. There must be some source of truth beneath the business which is in a measure successful, and the estimating cannot be entirely unreliable; I think there is a mathematical basis for the truth that is obtained even if it is obtained by guessing methods.

It is quite easy to have exact systems of bookkeeping and cost accounting, but it is inherently and mathematically impossible to have any exact system of estimating or predicting beforehand the cost of a job. The reason is that certain factors of the estimate have inherent errors in them, just as any human measurement or physical instrument has errors connected with it which are totally impossible to eliminate or reduce to any great extent. For instance, the labor item and other big items in estimating may contain a large error which cannot be eliminated or much reduced by any process, known or unknown.

It seems to me that one of the disguised merits of this paper is that it analyzes the relative importance of the different items and it shows some, such as depreciation of the automobile, etc., to be negligible. One of the beautiful laws of mathematics, which not one estimator in ten thousand knows, is that in any arithmetical sum we can eliminate all the items whose total does not exceed the biggest numerical error in any one item. If we have a labor item of \$50,000 and there is an error in that item of \$5,000, we will not decrease the reliability of the totalized result one iota if we drop out of consideration all the little items whose sum total is less than \$5,000. The philosophy of this truth is somewhat involved, but it is as true as any of the simpler laws of ordinary arithmetic.

It often happens that almost all the work of estimating comes in those little unimportant items that really add nothing to the accuracy of the result; and if the effort were expended on the principal items, the items that contain the biggest total, the reliability of the result would not be affected at all by forgetting the small things. This is unconsciously the basis of the guesswork estimate.

An estimate of \$39,549.26 is positively absurd and worse than useless. It is deceiving and full of small items which give an apparent accuracy that the result does not contain. The estimate should be stated with no greater accuracy than it actually possesses. There are people who think that the more petty arithmetic they expend on an estimate the more accurate it is. That has nothing to do with the accuracy. I think the one point that carries all through

engineering studies, engineering estimates, and engineering works, is that the error in the biggest item is what governs, and that everything less than that error should be neglected.

S. Montgomery: There are some points in the paper as read which are open to criticism. One of them is the effort to fix a proper ratio of overhead expense for any given class of business. I am constantly having manufacturers ask me the questions, How much overhead expense ought a foundry employing 50 moulders to have? How much overhead expense ought a machine shop with 600 hands to have? There has been a tendency among certified public accountants to encourage rule-of-thumb methods in the calculation of overhead expense. They sometimes give certain statistics, based on a few more or less special cases that they have handled, and draw an average overhead expense for all conditions. But I think that any efforts made to estimate a normal overhead expense in almost any line of business, unless conditions are so restricted as to eliminate practically all possibility of application elsewhere, are decidedly misleading.

The author states in one case that the overhead expense is estimated at 20%, but he thinks it would be more reliable to figure an overhead expense of 22% on a business of that size. This tends to give the impression that any contractor employing a certain number of men, in Fort Wayne say, and doing residence work, would have the same fixed overhead expense as another contractor, working in Chicago and wiring office buildings, with the same number of men.

The paper apparently covers only a very restricted class of work. I should judge, from the author's sum total of expenses as shown in Fig. 1, that he is doing just ordinary residence wiring in some small town, and possibly under those conditions his individual jobs are so small that it pays him to lump all indirect expenses with his overhead; that is, all expenses which are not actual first cost of material and actual wiremen's wages. However, in almost every line of contracting, unless the items are extremely small, as I judge they must be in this case, it is desirable to figure a good many of the indirect expenses directly against each job. It is improper, as a general thing, to lump any expenses whatever, if there is any chance to tie those expenses directly to some one job. For example, if one had an extra quantity of material coming in for one job and it could be delivered right at the place where it was to be used, he could charge freight and cartage on that material directly against the job instead of lumping it in with the freight and cartage necessary for handling the material he keeps in stock. Then, again, he might have some additional expense, such as railroad fare, if he has an out-of-town job; that railroad fare certainly ought to go against the special job and not against his general overhead expense. But I am assuming that the author is dealing with a very special case in his business, in which he has no large jobs, and possibly is justified in his present method of keeping accounts. Of course, it is difficult to criticise a man's cost-keeping system with-

out an audit of his books, and we have not the benefit of that in this case. He has no provision whatever in his scheme for distributing incidental expenses against individual jobs, but he should have at least mentioned that feature.

In regard to methods for cost-keeping on large contract jobs, there are two authors, members of the American Society of Mechanical Engineers (H. P. Gillette and Frank Gilbreth) who have published a good deal of information along the line of methods of cost-keeping for contractors, although they have not gone as deeply into the matter of depreciation as Mr. Rice says the American Electric Railway Association has done. The forms that they use and their general methods would be also applicable in any large electrical contracting business, although their work primarily has been in the line of railroad and structural contracting.

Mr. Rice: I would like to express appreciation of the two latter speakers, particularly on the point of the accuracy of an estimate. That is one of the most troublesome things about which to really get the right point of view. I recall very well some of my early experiences in that line. I felt that when I made an estimate I had to get in every small item of everything that went into the piece of work. The result was I nearly worked myself sick trying to account for every detail, and, as Mr. Pardee said, it was all of no avail, because if one has a certain probable error anywhere in his result it is of no avail to attempt to work any other part of the result to a greater accuracy than that. The result of this will be, of course, not to make the estimates unreliable; I did not intend to convey that idea in my earlier remarks; but the tendency will be to make estimates more reliable. The proper point of view and the proper result to get is, of course, the result which is just as accurate as one can get with the conditions with which he has to work. That is the primary thing and that is what makes for efficiency. One should take the material that he has to work with, and in case that material is his unit cost, take that material and make the best use of it possible to get the most accurate results. That means, as was stated, to consider only the detail figures in so far as they come within the probable error that one has in his fundamental units.

C. D. Wesselhoef: It occurs to me in assigning an overhead charge for work for a given year that there would no doubt at the end of the year be a difference between the amount assigned and the amount it really was. The sum I believe would be the probable error spoken of, which is impossible to determine beforehand, and that is an amount which I believe is usually assigned to contingency. It occurs to me that the proper way to handle this would be to determine at the end of the first year what that error was, and in the following year assign a contingency factor which, when added to all costs, would amount to the total error of the previous year. The item of contingency I believe has not been brought up

before this evening; it is, however, an item that must necessarily enter into contracting work.

Mr. Rice: The trouble with that, in contracting work, I should imagine, would be that if one had a series of contracts and a little error existed in each one, those contracts would close up prior to the end of the year and the question would arise as to what should be done with the surplus or the deficit at the end of the year. I presume that would have to be charged to one's own personal account.

Mr. Wesselhoft: Let us suppose that the overhead charge runs over the amount assumed at the end of the first year, and we find that we really had less overhead expense than we had figured on; then I believe that as fair an adjustment as could be made would be to subtract that amount from jobs the next year, so that at the end of the second year, according to the office figures at least, one would be even with the year before. On the contrary, if we ran behind, say, 5% during the first year we would on the succeeding year add 5% to every job, and if things turned out as they should at the end of that year we would be even for the two years.

Mr. Rice: That would be all right for you, but the man that paid the 5% excess now would be paying the 5% the man in the second year would save.

Mr. Wesselhoft: That is true, of course. That is the error one gentleman spoke of which we cannot determine, I believe.

Mr. Rice: It seems to me that the contractor ought to stand the gain or loss instead of the people for whom he is doing the work.

CLOSURE.

The Author: From Mr. Keller's discussion it is apparent he infers that the cost system under discussion applies only to small house-wiring contractors. The firm with which the writer is connected does over \$100,000 worth of business a year, and such an amount certainly does not represent a small business. This cost system is applicable to both large and small businesses. As stated in the paper, the overhead expense for the small business is proportionately greater than that for a larger one. The writer is glad that Mr. Wickum brought up the subject of the system recommended by the National Electrical Contractors' Association. This system deals only with the matter of keeping track of the material on estimates and on jobs. It does not provide any definite system for deriving the overhead expenses of any business. As stated in the paper, this association recommends certain percentages for overhead expenses, these percentages being proportionate to the size of the business. The writer tried to show in the paper an actual way of determining the expenses for each particular business instead of accepting a general average.

Mr. Pardee is entirely correct in the statement that while it is easy to have an exact system of bookkeeping and cost accounts, it is impossible to have an exact system of estimating. In the

abstract an estimate is a guess, pure and simple. Webster says: "An estimate is an opinion or judgment as to cost." While one may ascertain the labor item on one installation, certain elements of difficulty entirely unforeseen creep into each installation. It is these unforeseen difficulties that prevent the development of any eliminating process.

The relative importance of depreciation in any electrical contracting business is really small. This is of course due to the fact that no expensive machinery is required. The relative items being small, it is safe enough, for all practical purposes, to assume a depreciation on a straight line basis as Mr. Rice suggested.

The writer would also like to emphasize the importance of a statement made by Mr. Pardee and which the writer tried to bring out in the paper. This statement is that in any arithmetical sum, such as an estimate, small items whose totals do not exceed the greatest error in any large item can be eliminated. It is often very misleading to read an estimate of \$55,547.45. At a first glance one would be led to expect that the estimate is very accurate. As a matter of fact if that same estimate were written \$55,500 or \$55,600, the degree of accuracy in the latter two figures would be the same as that in the former.

It is evident that Mr. Montgomery does not fully understand the paper. The writer does not favor the assumption of any stated percentage for overhead as recommended by the National Electrical Contractors' Association. Every business should determine its individual overhead expenses as stated in the paper. This would answer the criticism made. It is also evident that Mr. Montgomery is not familiar with the contracting business in general. The very reason for omitting some of the expenses mentioned by him, such as railroad fare, is due to the fact that each estimate involving fare should have an allowance for fare. It is therefore evident that the item of fare being included in the general estimate should not be again included in the overhead.

The idea intended in this paper is to point out the relative importance of the different expenses which go in to make the overhead, and which at the same time cannot be assigned to any particular job. All such items, as material, railroad fare, etc., are parts that go to make up each particular estimate and are not covered by this paper. The overhead expense covers only general items whose value cannot be particularly assigned to any job.

It was not the intention of the writer to go into the cost system governing the preparation of the different items making up the total estimate. It is entirely beyond the scope of the writer in this paper to go into the different cost systems, or more accurately, accounting systems.

As expressed in the paper, the writer desires to point out the importance of the fact that no average percentage can accurately take care of overhead expenses. The "man hour" basis of expense proposed is a closer approximation to actual conditions than the systems used at present.

WATER PURIFICATION IN ILLINOIS

By EDWARD BARTOW* AND PAUL HANSEN†, M. W. S. E.

Presented October 20, 1913, at a Meeting of the Hydraulic, Sanitary and Municipal Section.

SOURCES OF WATER SUPPLY IN ILLINOIS.

All surface streams in Illinois are subject to pollution and yet many of them must serve as sources of public water supply for municipalities. Water purification, therefore, becomes necessary in order to secure water that is free from substances detrimental to the public health and acceptably free from suspended matter. Many communities in Illinois are fortunately able to obtain from wells, good public water supplies sufficient for domestic purposes. Among these are some of the largest communities in the state outside of Chicago. A large number of cities are, however, forced to use surface supplies either because a sufficient ground water supply is not available or because the ground water is not of acceptable quality.

The situation can be most readily understood by considering available sources of water supply throughout the state. For this purpose the state may be regarded as divided into three zones—northern, central, and southern. In the northern zone is included the territory north of a line drawn from Quincy to the point where the Illinois-Indiana line reaches Lake Michigan. In this zone, there is generally available an abundant quantity of excellent water from deep rock wells varying in depth from about 600 ft. to 2,400 ft.

In the central zone, which lies between the line above described and a second line extending from Danville to East St. Louis, many water supplies are obtained from deep drift wells.

The third zone, which includes the remainder of the state, contains very few wells yielding sufficient water for public water supplies. The glacial drift, where it exists at all, is too thin to produce wells with sufficient yield and the waters from rock wells are highly impregnated with mineral matter. The few exceptions to the rule are deep wells in the limestone on the southern slope of the Ozark uplift and a few deep wells in the alluvial deposits of the Ohio and Mississippi River bottoms which form the southern tip of the state.

Communities in the southern part of the state must, therefore, as a rule use surface water. Along the Mississippi River, even north of Quincy, it is difficult to secure ground water sufficiently free from mineral matter to render it acceptable for public water supplies. The Mississippi River cities, therefore, must use surface supplies, usually the Mississippi River itself.

The cities along the shore of Lake Michigan use the lake water because it is most convenient and most economical.

Numerous analyses have shown that the surface water supplies

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of Illinois, including Lake Michigan near shore, are unsafe as sources of public water supply. The opportunities for communities to own and control entire watersheds are very few and moreover, even if water supplies could be protected in this manner, purification would still be desirable owing to the presence of large quantities of suspended matter in nearly all of the streams of Illinois.

There are within the state of Illinois sixty-eight surface water supplies, of which thirty-three, including all the larger supplies, are now being subjected to some form of purification. Diagram No. 1 shows the progress of purification plant installation, and Diagram No. 2 shows the population served each year.

WATER PURIFICATION PLANTS IN ILLINOIS

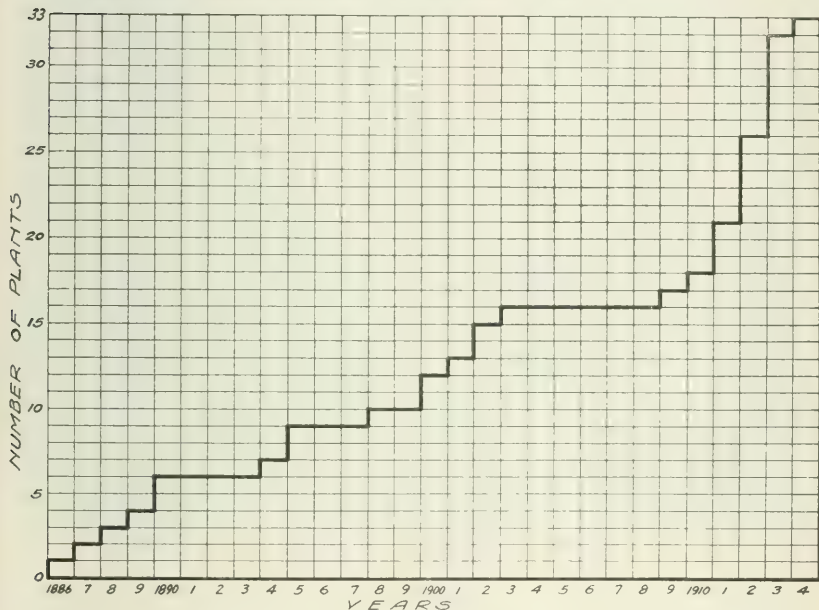


Diagram No. 1.

The first purification plant in Illinois was installed at Belleville in 1886. It consisted of two Hyatt pressure filters having a capacity of 300,000 gallons per day. This plant has since been abandoned. The first plant of this type in the United States was installed in 1874. A plant having a capacity of 1,350,000 gallons per day, consisting of six 10 ft. American filters, was installed at Elgin in 1888.

Two 8 ft. American pressure filters, having a capacity of 288,000 gallons per day, were installed at Streator in 1889. In the same year two 7 ft. American pressure filters, with a capacity of 220,000

gallons per day, were installed at Rogers Park. In the same year one 10 ft. American pressure filter, having a capacity of 226,000 gallons per day, was installed at Cairo.

The first gravity filter plant was installed at Quincy in 1892. It consisted of fourteen 12 ft. Jewell filters, having a total capacity of 4,000,000 gallons daily.

In 1903 the first concrete gravity filter plants were installed at Danville, with a capacity of 3,000,000 gallons per day, and at Moline, with a capacity of 4,000,000 gallons per day. To 1890 seven plants

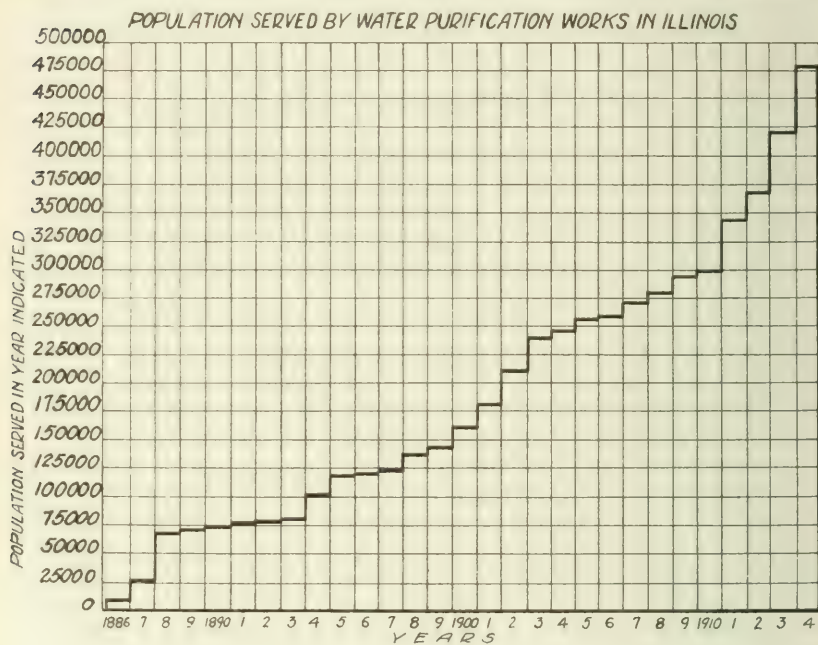


Diagram No. 2.

had been installed; to 1905 there were twelve; to 1910, seventeen; and since that time the increase has been rapid.

It is safe to predict that the growing recognition of the importance of having pure water supplies and the increasing demand for waters of good physical characteristics will result in the treatment of practically all surface waters within a few years.

PRESENT DISTRIBUTION OF WATER PURIFICATION WORKS.

At the end of 1914 there will be within the state thirty-six plants (see table) for the treatment of water and these will serve a population of about 490,000. This figure includes Rogers Park, but does not include a part of Chicago supplied with water sterilized by calcium hypochlorite.

Of the thirty-six plants, two, namely, Winnetka and Waukegan, are for sterilization with hypochlorite only, and will not be further considered; fourteen, including Rogers Park, are municipally owned and have a combined capacity of 43.42 million gallons per day and serve a population of 167,400. Eighteen owned by companies have a combined capacity of 59.05 million gallons per



Fig. 1.—Pressure Filters, Installed at Elgin in 1888. The Hydraulic Cylinders Above the Filters Actuate Devices for Agitating the Sand Bed.

day and serve a population of 293,700. Three owned by the United States Government have a combined capacity of 2.8 million gallons per day.

Considering purification plants with reference to type, there is one slow sand filter plant having a capacity of 300,000 gallons per 24 hours and serving a population of about 1,500. There are two plants utilizing sedimentation and coagulation only, which have a combined capacity of 3.7 million gallons per day and serve a population of 17,200. There are five plants with pressure filters having a combined capacity of 6.25 million gallons and serving a population of about 18,300. A sixth plant, at Elgin, now practically abandoned, owing to the availability of water from deep rock wells, may be added to this number. This plant would raise the combined capacity to 5,500,000 gallons per 24 hours and increase the popu-

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LIST OF WATER PURIFICATION PLANTS IN ILLINOIS, 1913

City	Population	Source of Supply	Ownership	Reaction Chambers		Coag. Basins	Clear Well Hours	Type of Plant	Chemicals Used	Cost of Plant Per M.G.D.
				Minutes	Hours					
R. I. Arsenal	1,000	Mississippi River	U. S.		4 5		1 5	Rapid Sand	A-H	
Kenilworth	1,000	Lake Michigan	P				5	Pressure Filters	A	
Naval School	1,200	Lake Michigan	U. S.		12 0		20 0	Slow Sand	A-H	
Ft. Sheridan	1,500	Lake Michigan	U. S.				1 5	Pressure Filters	A-H	
Hamilton	1,700	Mississippi River	M	3	3 0		2 5	Rapid Sand	A	
McLeansboro	1,800	Reservoir	M		10 0		24	Pressure Filters	A	
Bresce	2,200	Kaskaskia River	M				200,000 Pumpage	Coagulation and settling	L-L	
Warsaw	2,200	Mississippi River	M		4 0		18	Rapid Sand	A-H	
Winnetka	3,500	Lake Michigan	M				5 0	Sterilization	H	
Carlinville	3,700	Macoupin Creek	P		5 0		5	Rapid Sand	A	
Lake Forest	4,000	Lake Michigan	P				6 5	Pressure Filters	A-H	
Lawrenceville	4,000	Embarras River	P		3 0		1 0	Rapid Sand	A-H	
Charleston	6,000	Embarras River	M	8 0	4 2		3 0	Rapid Sand	A-H	
Macomb	6,000	Crooked Creek	M		4 2		1 0	Rapid Sand	A	
Pana	6,500	Reservoir	M				1 0	Rapid Sand	A-H	
Pontiac	7,000	Vermilion	P		1 2		1 5	Rapid Sand	L-L-H	
Mt. Carmel	8,000	Wabash	P		2 7		1 5	Rapid Sand	A-H	\$6,700
Murphysboro	8,000	Big Muddy River	P		8 4		2 0	Rapid Sand	L-L	
Mt. Vernon	9,000	Reservoir	P	13 0	4 0		1 5	Rapid Sand	A-H	
Rivers Pl., Ill.	10,000	Lake Michigan	M				3 0	Pressure Filters	A	
Kankakee	14,000	Kankakee River	P		5 0		4 0	Rapid Sand	A-H	
Carro	15,000	Ohio River	P		3 8		2 0	Rapid Sand	L-L-H	
Granite City	15,000	Wells, Slough and Wells	P		55 0		3 5 M.G.D. Pumpage	Coagulation, Settling and softening	L-H	
Streator	15,000	Mississippi River	P				2 5	Rapid Sand	A-H	
Alton	18,000	Vermilion River	P		5 0		5 4	Rapid Sand	L-L-H	
Freeport	18,000	Mississippi River	P		1 4		2 0	Sedimentation and Filtration	L	
Waukegan	18,000	Lake Michigan	M				9 0	Sterilization	H	\$300
Urbana and Champaign, Ill.	22,000	Wells	P		3 0		2 0	Aeration and rapid sand		
Evanston	26,000	Lake Michigan	M	19 0	1 7		12 0	Iron removal	A-H	
Rock Island	26,000	Mississippi River	M		12 0		6 0	Rapid Sand	A-H	\$10,800
Egin	27,000	Wells and Fox Res.	M				2 3	Pressure Filters	A	
Moline	27,000	Mississippi River	M				6 0	Rapid Sand	A	
Danville	30,000	Vermilion River	P		1 5		4 5	Rapid Sand	L-L-H	
Decatur	35,000	Sangamon River	M	16 0	4 0		9 0	Rapid Sand	A-H	\$15,400
Quincy	37,000	Mississippi River	P	16 5	4 6		6 0	Rapid Sand	A-H	11,100
E. St. Louis	65,000	Mississippi River	P		18 0		13 5	Boiled Sand	A-L-L-H	

LEGEND: A—Municipal, L—Private, U. S.—U. S. Government.

lation served to 45,300. There are two plants equipped with the pressure type of filter, but so installed that they act virtually as gravity filters. These plants have a combined capacity of 19,000,000 gallons per day and serve a population of 80,000. The most general type of filter is the open gravity, mechanical filter, and this type is used, or about to be used, at twenty-two plants having a combined capacity of 68.48 million gallons per day and serving a population of 291,100. Two iron-removal plants designed for the removal of iron from ground waters have a combined capacity of 6,000,000 gallons per day and serve a population of about 40,000.

PURIFICATION BY SLOW SAND FILTRATION.

The first effort to purify water in Illinois by slow sand filtration was made at Rock Island in 1898. The process soon proved



Fig. 2.—Exterior View of the Modern Mechanical Filter Plant at Rock Island. This Plant Is Built Within One of Four Abandoned Slow Sand Filter Units and Shows the Striking Contrast in Size.

totally unsuited for the highly turbid and often colored water of the Mississippi River at this point. In 1911 this plant was replaced by a modern mechanical gravity filter plant (Fig. 2). The only slow sand filter plant now in operation is at the United States Naval Training Station on the shore of Lake Michigan. The source of water supply is Lake Michigan, 1200 ft. from shore. The plant is of ap-

proved design and utilizes sand having an effective size of 0.32 mm. and having a uniformity coefficient of 2.60. The ordinary rate of filtration is 4.6 million gallons per day. During the first few years of operation, the Lake Michigan water was pumped directly to the surface of the filters, but the frequent high turbidity placed such a burden on the filters that during the past year a sedimentation tank, having a twelve-hour period of retention, was installed. The preliminary treatment thus obtained failed to materially improve conditions and it is now proposed to assist sedimentation by means of the addition of a chemical coagulant.

PURIFICATION BY SEDIMENTATION ASSISTED BY COAGULATION.

The two plants for treating water by coagulation and sedimentation only, are located at Breese and Granite City respectively. The plant at Breese has a nominal capacity of about 200,000 gallons per 24 hours and a sedimentation period of about 40 hours. Lime and iron are used as coagulants. This plant has been in operation something less than a year, and up to date has proved very inefficient. Part of the inefficiency may be explained by certain defects in design, but even with these defects corrected and with intelligent and painstaking operation, there will still be difficulty in securing as good results as have been obtained at the St. Louis water purification plant, after which this plant was modeled.

The other installation is at Granite City, where a most interesting treatment is adapted to the peculiarities of local conditions. The water supply is drawn partly from the Mississippi River, partly from a slough formed in an old channel of the Mississippi, and partly from tubular wells yielding water containing large quantities of iron. The Mississippi River or the slough water is mixed with the ground water in proportions found by experience to be suitable, and to the mixture is added a quantity of lime. The lime causes a rapid precipitation of ferric hydrate and also partially softens the water. The total sedimentation period is 55 hours. The plant will soon be abandoned and Granite City will receive its water from the East St. Louis water works.

MECHANICAL FILTRATION.

Filter Plants of the Pressure Type: The results obtained by means of pressure filters are more or less unsatisfactory. At McLeansboro, population 1800, there is a small pressure filter with a nominal capacity of 240,000 gallons per day, provided with neither coagulating basins nor clear-water storage. The water as it comes from the filters is generally turbid and the bacterial removal is very low. The plant could be improved by modifications in the coagulant preparation and feed devices, but it is not probable that it will give entire success.

There has been greater success at Kenilworth, where there are pressure filters having a nominal capacity greatly in excess of the

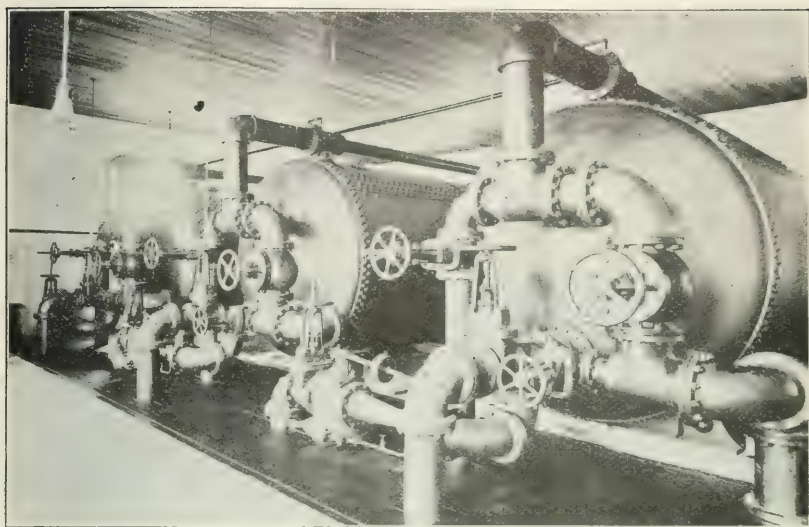


Fig. 3.—Pressure Filter Plant of Modern Construction at Ft. Sheridan.

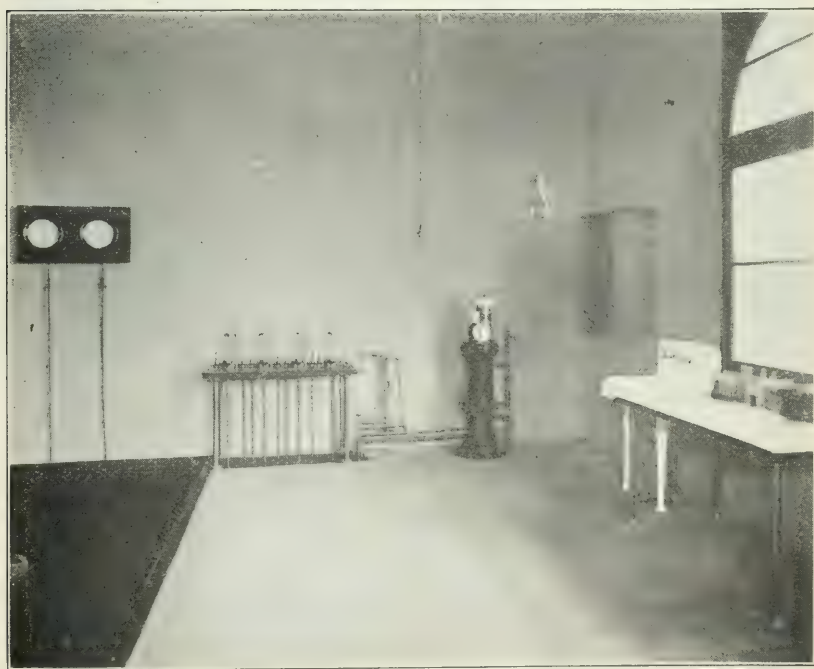


Fig. 4.—Ft. Sheridan Filter Plant—Sampling Taps in Center.

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consumption. At Lake Forest a safe water is obtained with pressure filters assisted by sterilization with hypochlorite, but at times the water in the mains has been turbid. The good results at Lake Forest must be in large part ascribed to the maintenance of systematic analytical control.

The new plant at Fort Sheridan (Fig. 3) has a capacity of 1,500,000 gallons, but it is rarely called upon to supply more than 500,000 gallons. It has not been under observation long enough to determine its success or non-success. In the absence of coagulating basins, much difficulty has been encountered in securing good coagu-

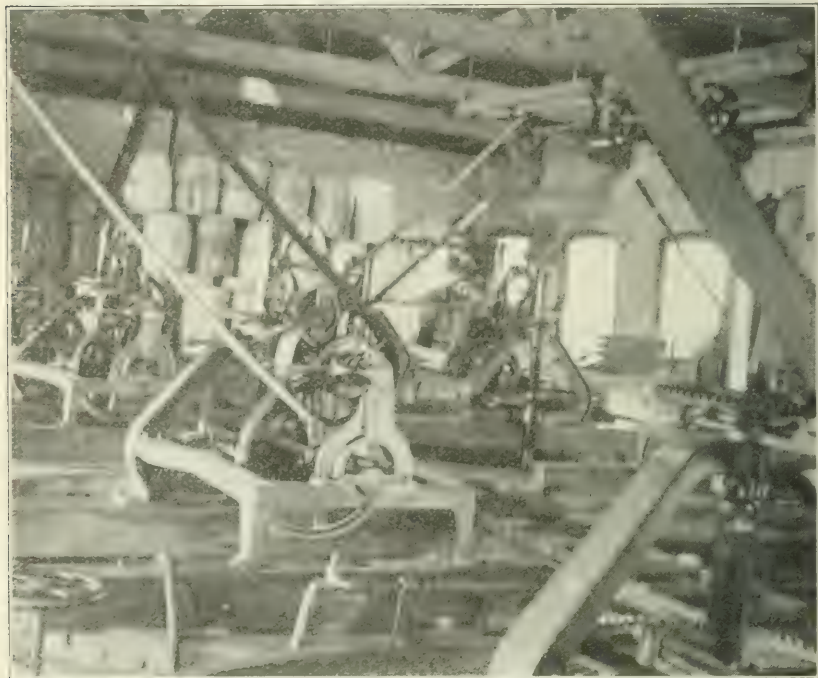


Fig. 5 -Interior View of Old Warren Filter Plant at Decatur. Note the Elaborate Machinery for Operating Sand Rakes.

lation of the water, especially in cold weather, and it is probable that some of the alum passes through into the filtered water. The bacterial results (Fig. 4) may be maintained reasonably low by the use of calcium hypochlorite, for which the plant is equipped. With the present small consumption, the plant, if properly operated, should be capable of delivering a reasonably clear and safe water to the consumers.

Modified Pressure Filters: Filters of the pressure type, but operated as gravity filters, are used at East St. Louis and Streator.

They are enclosed in steel shells just as are ordinary pressure filters, but otherwise they operate in the manner of gravity filters; that is to say, the water flows into them under a head of a few feet from the coagulation and sedimentation basins and the effluent passes into a clear-water reservoir. Thus the filters are not at all subject to the influence of the pumps. When such filters are properly designed and properly controlled, they give good results, but they have the serious disadvantage of relative inaccessibility. Both of these plants are under careful management, and available data indicate that they produce regularly acceptable results.

Mechanical Gravity Filters: The open gravity type of filter has come to be recognized as the standard installation, and, as will be observed in the table previously referred to, the great majority

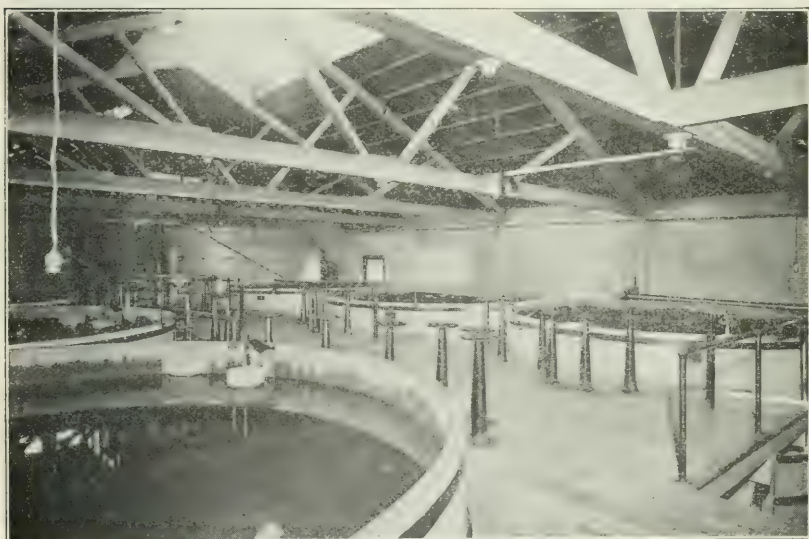


Fig. 6.—Operating Floor of Filter Plant at Cairo. Note Large Wooden Sedimentation Tanks in Left Background.

of plants are of this type. Within the state of Illinois may be found plants representative of almost every stage in the development of gravity filters. The old plants at Quincy and Decatur (Fig. 5), both now being replaced by new and larger plants of most modern construction, are examples of early practice. At Quincy in the nineties a series of important experiments were conducted which greatly increased our knowledge with reference to the use of lime and iron as coagulants. From these we pass through later developments at Cairo (Fig. 6), Pontiac, Alton, Danville, Moline, and finally reach the most up-to-date installations now in use at Rock Island (Fig. 7), and under construction at Quincy, Decatur and Evanston.

A group of the older plants, including the Cairo plant and the old plants at Quincy and Decatur, give poor results, primarily because they are now worked beyond their normal capacity. At the present time, however, these old plants are generally producing a safe water as a result of the addition of calcium hypochlorite as a sterilizing agent.

There are plants at Pontiac, Warsaw, and Lawrenceville of old design, but of comparatively recent installation. The Pontiac and Lawrenceville plants are faulty in design and operation, but hypochlorite is now maintaining the water safe in each instance.

Component Parts of Mechanical Filter Plants: Mechanical fil-



Fig. 7.—Operating Platform—Rock Island Filter Plant.

tration in Illinois can be most advantageously discussed in a brief space by discussing the several component parts in the light of Illinois practice rather than by describing plant by plant.

Coagulant Preparation and Feed Devices: The chemical preparation and feed devices constitute a most important part of a mechanical filtration plant, though perhaps the least costly part. It is essential that the chemicals be added in the proper quantities and uniformly. But little real advance has been made in the design of the chemical preparation and feed devices. An early type, as exemplified in the Egyptian water wheel arrangement at Decatur (Fig. 8), still gives very satisfactory results as compared with the

more modern designs. This device consists of a dipper wheel made of bent piping, revolving partially submerged in a tank full of solution, the surface of which is maintained at a constant level. The wheel is actuated by a propeller placed in the raw water inlet pipe, so that it revolves and dips up solution at a rate approximately proportional to the volume of water entering the plant. The solution, which is made of a suitable strength to secure the requisite application to the raw water, flows out through the hollow hub of the dipper wheel and is conveyed by suitable piping to the desired point of application.

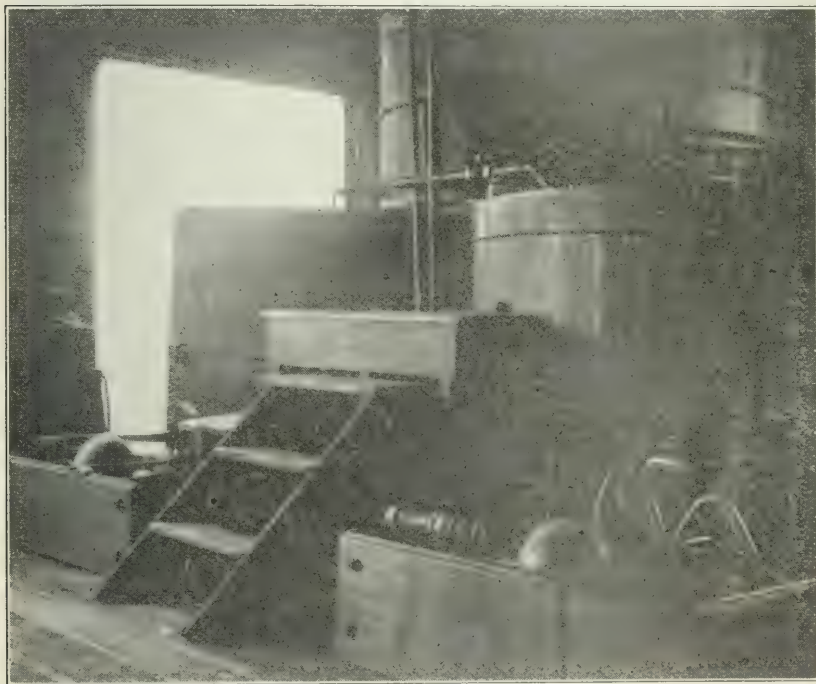


Fig. 8.—An Early Form of Proportional Chemical Feed of the Egyptian Water Wheel Type. Still Doing Satisfactory Work.

A very common and generally satisfactory device for maintaining a uniform flow of coagulant is the so-called constant head orifice box (Figs. 9 and 10). In this device a constant head of solution is maintained over a free discharging orifice of sufficient size to deliver the requisite quantity of solution. In the more modern types, the orifice is made adjustable so that the application of chemical may be varied without changing the strength of solution. A somewhat ingenious modification of the principle involved in this device is found at Alton. This appa-

ratus is more compact than the ordinary constant head orifice box and is arranged for ready flushing out with clear water when desirable.

At Mt. Carmel is a simple form of apparatus (Fig. 11) which applies the chemical at a rate directly proportional to the volume of water entering the plant. It performs the same function as does the Egyptian water wheel above described, but somewhat more accurately. The water entering the plant is received in a small



Fig. 9.—Chemical Storage Tanks of Concrete and Enamel Lined Orifice Boxes at Mt. Vernon. On Right Are Shown Loss of Head Gages and Valve Stands in Front of Filters.

chamber with an orifice in the bottom. Within the chamber is a float connected to one end of a lever arm, the other end of which is connected to an orifice attached at the end of a flexible pipe placed within a constant level solution tank. The apparatus is so adjusted that the head of water over the orifice in the inlet chamber to the plant is a fixed multiple of the head of solution over the orifice in the solution box.

At some of the plants in the state, notably at Cairo and at the new Evanston plant, solution pumps will be used to discharge the chemical into the raw water at the proper rate. The chemical pumps at Ft. Sheridan and Waukegan are actuated by the pulsations of the service pumps by means of water connections. Their rate of



Fig. 10.—Chemical Solution Tanks and an Orifice Feed Box, All of Reinforced Concrete. In Use at Rock Island.

operation is, therefore, proportional to the rate of operation of the service pumps.

Plain Sedimentation Basins: Plain sedimentation is an unusual preliminary to chemical coagulation and sedimentation and filtration, but appears to have considerable value in the treatment

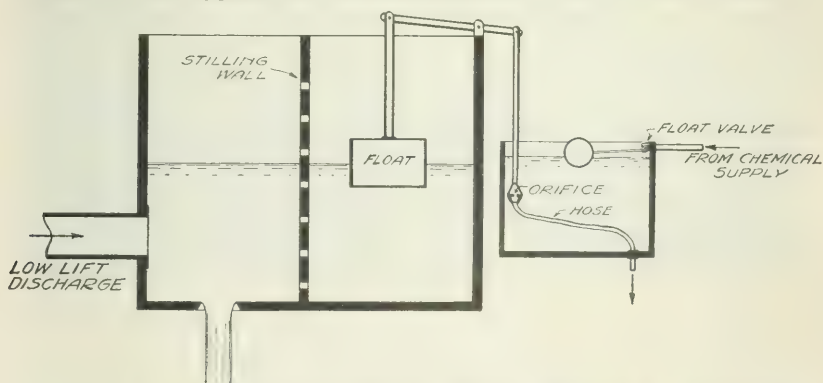


Fig. 11.—A Simple Device for Feeding Chemical Solution at a Rate Proportional to the Rate of Flow of Incoming Raw Water from Low Lift Pumps. In Use at Mt. Carmel, Ill.

of waters carrying heavy turbidities in that it economizes on coagulant and produces a more uniform water to handle. Preliminary sedimentation is systematically used at East St. Louis (Figs. 12

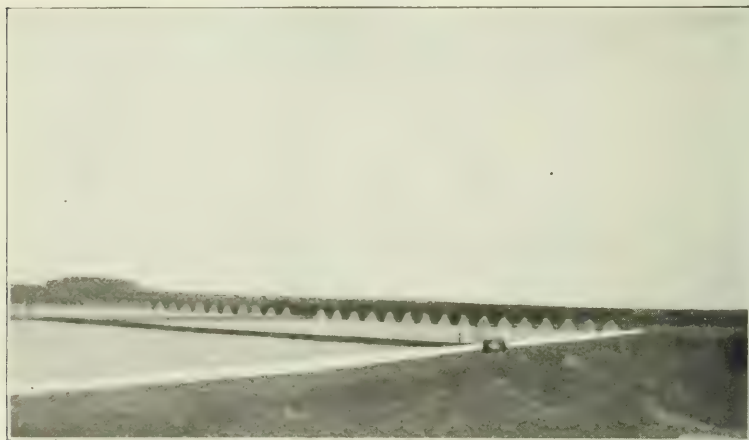


Fig. 12.—East St. Louis—Preliminary Settling Basin in Operation, Inlet End.

and 13), where the retention period is approximately ten hours. At Rock Island it is also used, the retention period being about twelve hours; the arrangement is such, however, that coagulant may



Fig. 13.—East St. Louis—Cleaning Preliminary Settling Basin.

be added at the entrance of this basin when desired. At Mt. Vernon and Pana a prolonged period of sedimentation is had in impounding reservoirs, but these cannot be regarded as parts of the filtration plant.

Reaction Chambers: Within the last few years the reaction chamber has come to be recognized as an important part of a mechanical filter plant. Its function is to maintain the water in gentle agitation after the coagulant is added until the reaction is complete. Five plants in Illinois include this feature, namely, those at Evanston, Decatur (new plant), Quincy (new plant), Charleston, and at Mt. Vernon. All these plants are now under construction or were completed during the present year. Practice varies with respect to the retention period from eight minutes at Charleston to nineteen minutes at Evanston. The reaction chamber is generally a conveniently shaped compartment adjacent to the coagulating basins and highly



Fig. 14.—General View of Recently Completed Small but Modern Filter at Mt. Vernon. Coagulating and Sedimentation Basin in Foreground. Reaction Chamber Is Placed under Projection to Building.

baffled to produce a velocity of between $1\frac{1}{2}$ ft. and $1\frac{1}{2}$ ft. per second. The baffles are generally of wood and so arranged that they may be moved from time to time to meet the requirements of varying quantities of water treated by the plant.

Coagulation and Sedimentation Basins: The general tendency in filtration practice in recent years in this state, as well as in others, has been to increase the retention period in the coagulation and sedimentation basins (Fig. 14). These basins must, of course, be designed with special reference to the water to be handled and

may vary within wide limits because of this consideration. On the other hand, the advent of the reaction chamber has probably checked greater increase in size because this adjunct now performs more efficiently and in less space what sedimentation basins were formerly counted upon to do.

Notwithstanding the fact that coagulating and sedimentation basins (Fig. 15) have been regarded as more and more of a necessity, and are counted upon to do more and more of the work of purification, thereby constituting filtration a final though very im-



Fig. 15.—General Interior View of Moline Filter Plant. Coagulating and Sedimentation Basins in Foreground. Filters in Background.

portant finishing process, yet some of the latest designs include no coagulation and sedimentation; for instance, those at Pana, Ft. Sheridan, and McLeansboro. Aside from these exceptions, coagulating basins are used, and the periods of retention vary from one and one-half hours at Danville to eighteen hours at East St. Louis. The new plant at Evanston will have basins with a retention period of 1.7 hours. Here the turbidity will be only occasionally heavy and never difficult to handle. The new plant at Decatur will have basins of four hours' retention to handle the moderately troublesome water of the Sangamon. At Quincy 4.6 hours will be used,

combined with much elasticity in operating arrangements, to meet the requirements of the very troublesome water of the Mississippi River.

Coagulation and sedimentation basins are generally provided in duplicate, and sometimes these basins are of different sizes to give greater range in the retention periods available. This latter arrangement obtains in the new plant at Quincy. In the larger and more modern plants, the basins are arranged so they can be operated in series or in parallel, with or without the reaction chamber, and sometimes still other combinations are provided. In the smaller plants, however, the tendency in the design of sedimentation and

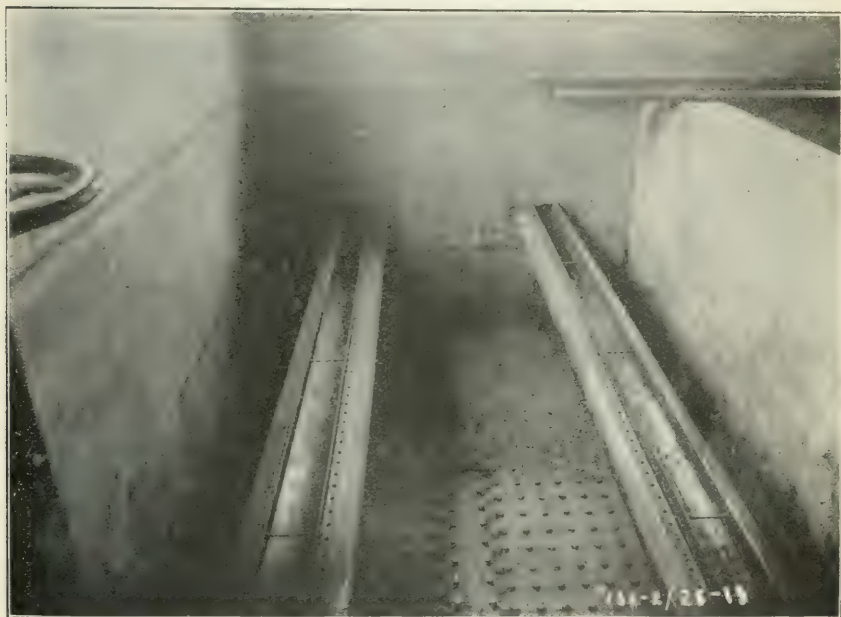


Fig. 16.—Interior View of a One Million Gallon Filter Unit at Mt. Vernon, Showing Central Manifold Casting, Strainer Heads, a Portion of Gravel in Place and Waste Water Troughs.

coagulation basins is toward simplicity. With the advent of the reaction chamber even the duplicate basin is omitted, as this will afford all necessary preliminary treatment during clear-water periods.

Filters: The filters proper vary greatly in appearance, ranging from the old Jewell high wooden tanks 12 ft. in diameter and 12 ft. high installed in 1891 at Quincy, to the 36 ft. by 23½ ft. concrete units of the new Evanston plant. With the exception of the old Warren filters at Decatur installed in 1893, there is very little essen-

tial difference in the interior arrangements between the old and the new filters. The difference lies almost wholly in progressive improvements in details of design. All have in their bottoms a grid or system of conduits (Fig. 16) with perforated brass plates or strainer heads for collecting filtered water and distributing wash water. All have a sand bed of 30 in. to 3 ft. in thickness. All have the usual connections for admitting raw water at the top, for drawing off filtered water at the bottom, for filtering to waste, for admitting clear wash water at the bottom and drawing off soiled wash water at the top. All operate with a range of filtering head up to 10 ft. The greatest differences lie in the method of agitating the sand. The older types have the cumbersome revolving rakes for agitating the sand bed, while the later designs are agitated by air blown in at the bottom, or rely entirely on the wash water when applied at a rapid rate. The old-fashioned rakes are not, however, regarded as obsolete and only during the past year a small plant at Warsaw was equipped with this agitating device.

The old Warren plant at Decatur represents a variation from the general type, in that the filters have double bottoms instead of grids for conduits, and there is a continuous perforated sheet of brass over the whole bottom of each filter instead of the small perforated strainer heads or plates. There is also a very thin bed of very coarse sand or crushed quartz not over 22 in. thick, and to offset the slight frictional resistance thereof, the filters are not permitted to operate under a head greater than 2 ft. There is also a difference in the relation of the several filters to each other, more particularly in the mode of control and washing. But as this type of filter is practically discarded and only of interest from an historical standpoint, further description will be omitted.

The most pronounced differences in design, aside from those already mentioned, between the old and new types of filters are:

First: The change from the circular to the rectangular form which adds nothing to the efficiency, but greatly improves the general layout and is economical of space and material.

Second: The increase in size of units which likewise adds nothing to efficiency, but makes for economy of construction and facilitates operation.

Third: The introduction of a central gutter, an outgrowth of the increase in size of units which virtually divides a filter into two units, though still retaining a single set of inlet and outlet connections. This adds nothing to the efficiency and is a mere convenience of arrangement.

Fourth: The introduction of concrete collection and distribution systems, which cheapens cost of construction and permits of readily using larger conduits thus reducing frictional resistance.

Fifth: The more careful design of troughs for carrying off soiled wash water so that the same may be carried off evenly and rapidly from all parts of the filter. This improvement was partly

imposed by increased size of units, but also adds to the effectiveness of washing.

Filter Control: In the older plants the filters are always controlled by hand-operated valves which renders the washing of filters a time-consuming and awkward operation. In the larger modern plants hydraulically-operated valves are the rule. This greatly simplifies the labor of cleaning a filter, permits of a simpler and better arrangement of the pipe gallery in front of the filters, and makes

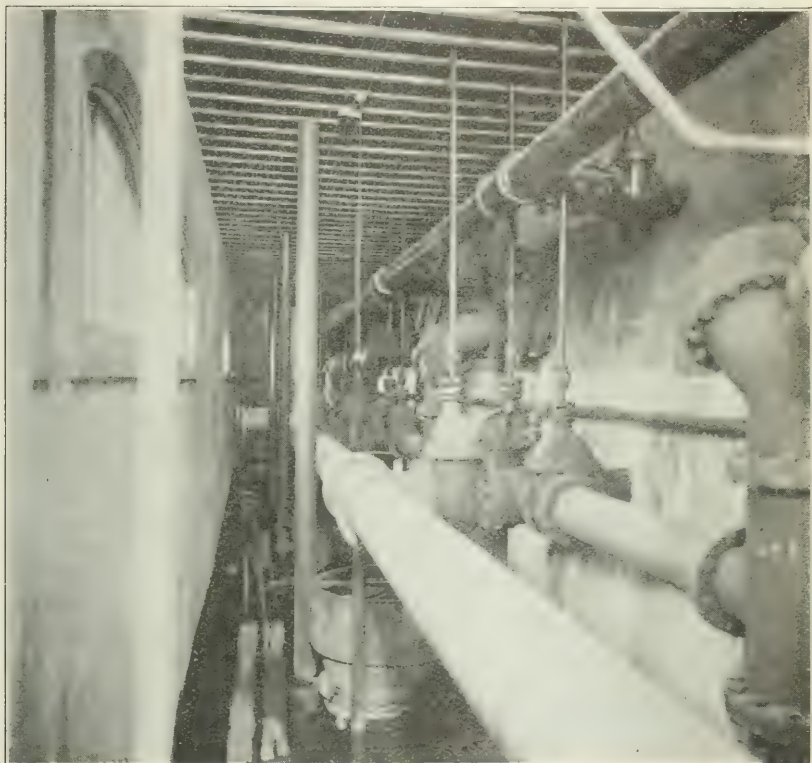


Fig. 17.—Pipe Gallery for Single Row of Filters at Moline. Note in Background Under Large Pipe a Rate Controller of the Float Type.

possible a neat-appearing operating floor. The main objection to hydraulically-operated valves is the annoyance of "sticking." This can, however, be largely overcome by using parallel-seated self-adjusting disk valves and by systematically cleaning the hydraulic cylinders at proper intervals.

The necessity for controlling the rate of filtration automatically is becoming more and more recognized. Even early filters had means of control, but until recently many filter operators held that

an occasional partial turn of the effluent valve gave sufficiently close control. This is in large measure true, but this method places too great reliance on the watchfulness and reliability of the filter attendant. Most of the plants in the state are without automatic rate-controllers. There are three general types of filter rate-controllers in use, namely, the float type, the disk type, and the meter type. The float type in principle is simply a device for automatically maintaining a fixed head over an orifice of definite size or over a weir, generally the former. This type of controller is exemplified by those at Cairo, Pana, Moline (Fig. 17), and Danville. The disk type maintains a constant rate of flow by producing a constant head on a submerged orifice by means of properly weighted disk and balanced valve fastened to the same shaft. The dropping of the disk causes the valve to open wider and the raising thereof causes it to close. These controllers have a tendency to stick, but when carefully made and provided with properly designed valve ports, they give good results. Controllers of this type are installed at Rock Island (Fig. 18), Macomb, Alton, Mt. Vernon and Charleston. The meter type of controller depends for its operation on maintaining a constant difference of head between the throat and entrance to a Venturi tube. Any variation is transmitted to a diaphragm which actuates a pilot valve and which in turn operates a gate valve. The variations in head may also be transmitted by electrical means to the gate valve. Controllers of this type are in use at Ft. Sheridan and are about to be used in connection with the two new plants at Quincy and Decatur.

Loss of head gages are devices for observing the loss of head suffered by the water in passing through a filter. Therefore, they indicate the condition of the filter sand beds and give the attendant a means whereby he can ascertain when a filter requires washing. The loss of head gages are of two types, namely, the indicating and the recording. The indicating are suitable for ordinary purposes, but there is a great advantage in having a record of the filter runs. Loss of head gages are not in as general use as they should be and in some plants they are permitted to become dismantled. Those plants having loss of head gages of the indicating type in use are Moline, Kankakee, Mt. Vernon, Macomb, Charleston, Warsaw, Hamilton and Ft. Sheridan, and Rock Island Arsenal. Rock Island has recording loss of head gages.

Clear Water Storage: The provision made for clear-water storage varies greatly. In some plants it is scarcely more than a suction pit, while in others the storage is as much as twenty-four hours. The size of clear-water basins will depend largely on the storage available in distribution and equalizing reservoirs connected with the distribution system. For example, at Quincy the retention period is only 0.7 hour in the clear-water basin, but there is a reservoir holding about fourteen days' supply on the distribution system. At Rock Island the clear-water basin, together with the

filter plant, is at a high elevation and is directly connected with the distribution system. The storage period is twenty-four hours.

Generally speaking, there is a tendency to make the clear-water basin too small, when it is considered that the filters must operate at a uniform rate no matter what the daily and hourly rate of consumption may be.

Accessories: Filter plants have a number of important accessories, the design and arrangement of which vary considerably in practice. As a rule, water from the source of supply must be raised to the filter plant ordinarily through a low lift. For this purpose electrically or steam-turbine driven centrifugal pumps are nearly always used because of their special adaptability to such service.

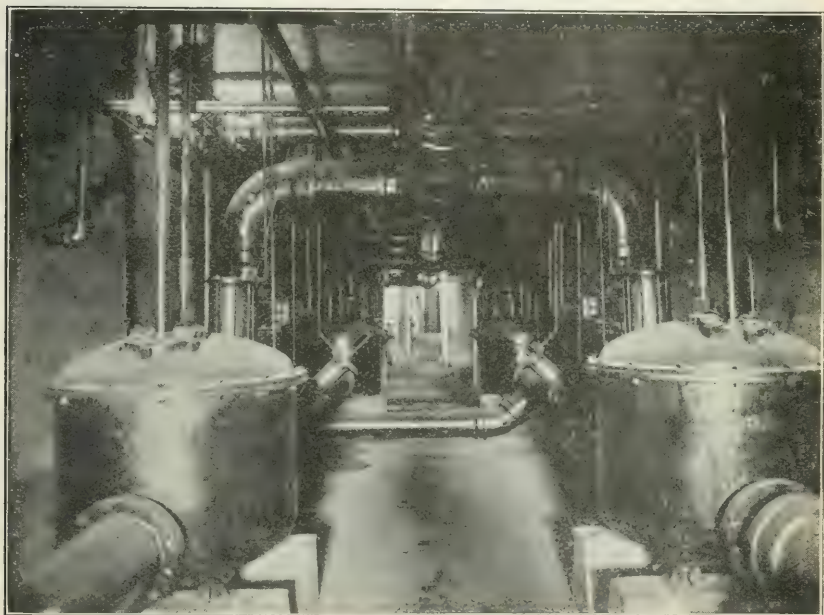


Fig. 18.—Pipe Gallery Between Two Rows of Filters at Rock Island. Illustrates Present Tendency to Secure a Clear Passageway and Ready Accessibility to All Parts. On Right and Left Fore-ground Are Shown Filter Rate Controllers of the Disk or Submerged Type.

The quantity of water pumped and the head pumped against are constant or nearly so and the total lift is not great. The water often contains grit and is often hard on piston and plunger pumps.

Wash water is supplied to filters in several ways, namely, (1) by drawing from the distribution system, (2) by installing low-lift centrifugal pumps taking suction from the clear well, each with

a capacity sufficient to furnish wash water for one filter, and (3) by having an elevated storage tank supplied by small pumps starting and stopping automatically or by having a connection with the distribution system. In modern practice the storage tank is considered the most economical and desirable and is the method adopted for all of the new and larger plants now under construction. In all these cases small automatically-controlled pumps will be used, but there will be in the case of the Quincy plant an emergency connection to the distribution system.

In all of the plants in this state where air agitation obtains, blowers are used, but in modern practice elsewhere compressors and air storage tanks are in favor.

Storage of chemicals is an important factor and often adequate provision is not made therefor. The storage space desirable will vary with local conditions, character of water to be treated, shipping facilities, etc., but even in small plants there should be sufficient storage available to permit of buying in carload lots. In the larger plants, large storage may be advisable in order to take advantage of market conditions.

Every filter plant should have some provision for office space, laboratory, and toilet and locker rooms. Too often these matters are neglected in the smaller plants and where proper conveniences are lacking the operation of the plant is almost certain to suffer.

A word may be said with reference to the appearance of superstructures. Progress in this connection is being made, for it is unusual nowadays to see wooden or cheap brick barn-like structures built over large and important plants. But the superstructures for the smaller plants are still very crude in design. The additional expense for rendering these structures attractive is small compared with the cost of the whole plant, and it is eminently fitting that water-works buildings in general and filter buildings in particular should present a neat, clean and inviting appearance.

GENERAL ARRANGEMENT OF FILTER PLANTS.

The arrangement of mechanical filter plants varies greatly, depending on size of plant, local topography, and other local requirements and depending on the ideas of the designing engineer. A plan that meets with general favor is what may be called the head house plan in which the several parts of the plant are grouped about a more or less centrally located head house. The raw water is received at the head house, treated with chemicals, diverted to the reaction chambers and coagulating basins, then returned to the head house and diverted to the filters. The head house superstructure also houses chemical preparation and feed devices, machinery, laboratories, toilet rooms, locker rooms and offices. In some cases the head house is large enough for storage of chemicals also.

Frequently filter plants are not designed with a proper consideration for future extension and this in one or two instances has caused much awkwardness in making additions.

Laboratory Control: Laboratory control is feasible and necessary in even the smallest plants to secure best results. (Fig. 19.) Under actually existing conditions, laboratory control is especially necessary in the small plant because such plants are as a rule less perfect in design and construction than the larger ones. The tests required are very simply carried out and can, if necessary, be entrusted to a man of ordinary intelligence and industry, even though he has no scientific training. The determinations that should be made are turbidity, color, alkalinity, the number of bacteria and gas formers in the raw and filtered water. Solutions should also be tested, especially hypochlorite solutions. Should there be a mu-



Fig. 19.—Control Laboratory at the Filter Plant of the Danville Water Co.

nicipal or industrial laboratory near by, it may perhaps be better in the case of small plants to have the bacterial work done there, but there is no reason why the simple physical and chemical tests above enumerated should not be made in even the smallest plants.

In conclusion, it is interesting to note that wherever reliable records can be obtained they show a marked reduction in typhoid fever even where the efficiency of the plant is not as great as it should be. At Decatur there have been no accurately kept typhoid fever records, but the city has a reputation of being quite free from the disease. Much of this must be attributed to the old Warren filter plant, though its average efficiency, based on bacterial removal during late years, was only 90%. At Moline and Rock Island the

typhoid death rate has been low since the installation of filters. Shortly before placing the new plant at Rock Island in regular operation, there was a serious epidemic of typhoid, showing the great danger that lurks in the use of the untreated river water.

It is unfortunate that there is not in Illinois a better system for the registration of vital statistics, since these form the best means whereby we may judge the efficiency of water purification works as well as estimate the need of such works.

Notwithstanding this lack of good vital statistics, the many advantages of having a clear, colorless water makes it safe to predict that within a few years we will see the purification of all muddy and colored surface-water supplies.

DISCUSSION.

Langdon Pearse, M. W. S. E. (Chairman): The authors of the paper have given a summary of the existing status of water filtration in Illinois. It may be of interest to many, and particularly those who attended the excursion on Saturday afternoon, October 11th, to have some details of the design and construction of the filtration plant at Evanston.

The installation of a plant was urged by the State Water Survey and the health officials of Evanston, because of the poor condition of the water in Evanston, both from the hygienic and aesthetic standpoint. The intake is only 1 1/16 miles offshore, well within the range of drift for the sewage of Evanston and Wilmette, the greater portion of which is discharged on the lake front. In the winter of 1911-1912 a severe threatened epidemic of typhoid was averted only by the emergency use of chloride of lime.

When the matter was agitated in 1912, Mr. W. W. Jackson and the writer made a report in August of that year, recommending the construction of a plant of the rapid-filter type. By a popular vote in the same fall, a bond issue was authorized. Plans and specifications were prepared by Mr. George W. Fuller, of New York City, and the writer, on which bids were received in April. Active construction work commenced in June, 1913, under our direction, with Mr. C. G. Gillespie as the resident engineer.

Doubtless some of you will ask why the plant was made of 12,000,000 gallons' capacity for an estimated population of about 30,000. The reason for this is the abnormal daily average pumpage in the summer time, the daily average frequently running 12,000,000 gallons per day for a continued period of hot weather, with peak loads for four hours as high as 17,000,000 gallons per day in the afternoon. The average daily pumpage by the year has been about 6,000,000 gallons per day for the last ten years, the effect of increase of population having been taken care of by inspection of services and leaks. This large use of water is due principally to lawn sprinkling, since the pumpage drops suddenly in summer time on cloudy, and particularly on rainy, days. With the condition in

mind of continued daily loads, and the possibility of a healthy growth of population, 12,000,000 gallons capacity seemed a nominal size for this community. This rating is based on the usual rating of 125,000,000 gallons per acre per day.

The filter plant is located on Sheridan Road about one mile north of the center of the city on a site adjoining the Northwestern University and 300 ft. from the existing city pumping station. A low-lift pumping station is to be built adjoining the present pump-

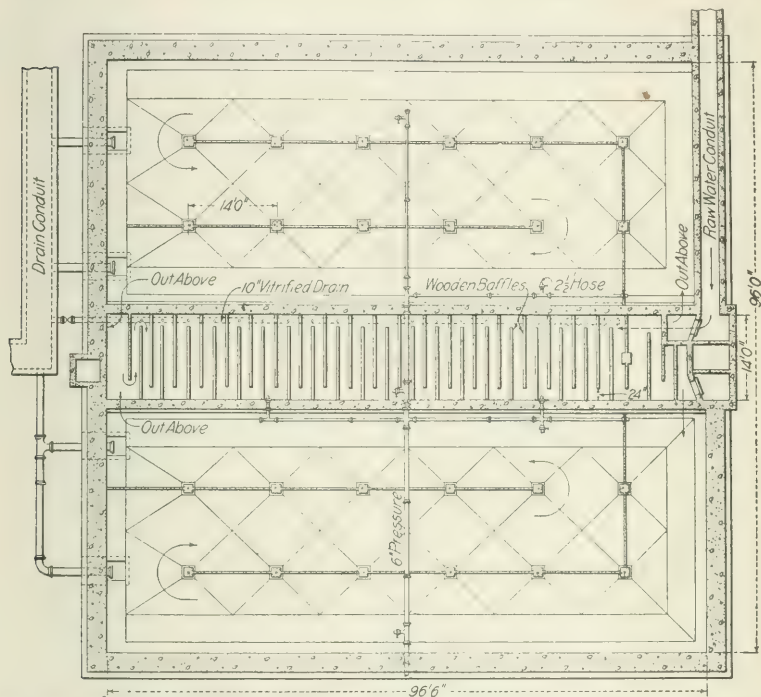


Fig. 20.—Plan of Mixing Chamber and Coagulating Basins, Showing Baffles.

ing station, which will be equipped with three centrifugal pumps, two of 10,000,000 and one of 6,000,000 gallons per day, capacity. These will be geared to steam turbines, the entire outfit being furnished by the DeLaval Steam Turbine Company, with a guaranteed duty in excess of 69,000,000 ft.-lb. per 1,000 lb. of dry steam for the larger units. A 30 in. cast iron force main will conduct the raw water to the entrance to the mixing chamber, a Venturi meter being placed on the line to measure the pumpage.

The mixing chamber is about 96½ ft. by 14 ft. in size, with a depth of 18 ft., having a total capacity of approximately 170,000 gallons, giving a nominal mixing period of 20 minutes. The basin is to be constructed entirely of reinforced concrete, divided into

bays by wooden baffles to maintain velocities of approximately 1 ft. per second. The mixing chamber lies between and is part of two coagulating basins, each about $39\frac{1}{2}$ by $96\frac{1}{2}$ ft. in size, and 15 ft. deep, having a combined capacity of approximately 830,000 gallons, giving a nominal period of sedimentation of 1 hr. and 40 minutes. These are to be constructed entirely of reinforced concrete with a groined arch roof, each compartment being divided by two concrete baffles into three bays to insure circulation.

The coagulated water will flow in a concrete channel across the space left for the extension of the filters to six rapid-filter units, each $23\frac{1}{2}$ by 36 ft. inside diameter, having an aggregate filter surface of 4425 sq. ft. The filters will be grouped on both sides of a pipe gallery, over which is a platform with an operating table for each filter. All the filter tanks, floors and roof will be of reinforced concrete. Hydraulic valves will be used throughout, the controllers for the filters being of a modified Vivian type. The wash-water drain, filtered-water conduit and raw-water conduit will be built one over the other, forming a reinforced concrete structure down the center of the pipe gallery. The house covering the operating floor and a part of the filters will be of brick with a concrete roof, the inside being lined with a light yellow vitrified brick. The design is so made that the operator can see the entire filter bed at time of washing.

Both filters and head house are placed above a covered filtered water reservoir, 154 by 161 ft. in plan, 12 ft. deep, divided into two basins having a total capacity of approximately 2,000,000 gallons. This basin has a groined arch roof, reinforced where necessary to carry the weight of the head house and filters. The standard spacing for the arches is 12 ft. 6 in. on centers, with a rise of 2 ft. 9 in. and a thickness of 6 in. at the crown. The foundation is of firm clay so that the thickness of the floor arches is only 6 in. at the thinnest point.

The two-story head house at the head of the filter gallery has two wings, one story each, built of reinforced concrete and brick with a tar and gravel roof. The dimensions of the head house are approximately 28 by 91 ft., and of the filter wing 75 by 36 ft. In the head house will be placed the tanks and apparatus for the proportioning and application of the coagulating and sterilizing chemicals, the recording gages, laboratory office, and chemical storage. The second floor of the head house will be served by an hydraulic elevator.

The design of the rapid-filter units includes an under-drain system with perforated brass plates, set at the bottom of valleys in the fashion of the Minneapolis, Grand Rapids, and other plants. A novel feature, however, will be the omission of the wire screen, and the use of 12 in. of graded gravel, on top of which the sand will be placed. The wash is to be high-rate water wash, supplied by a gravity feed from a steel tower tank of 100,000 gallons capacity to be

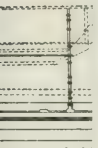
Raw Water For

Existing Coal

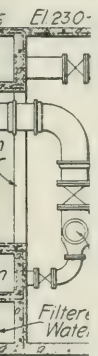
Boiler Room

New

Existing Pump

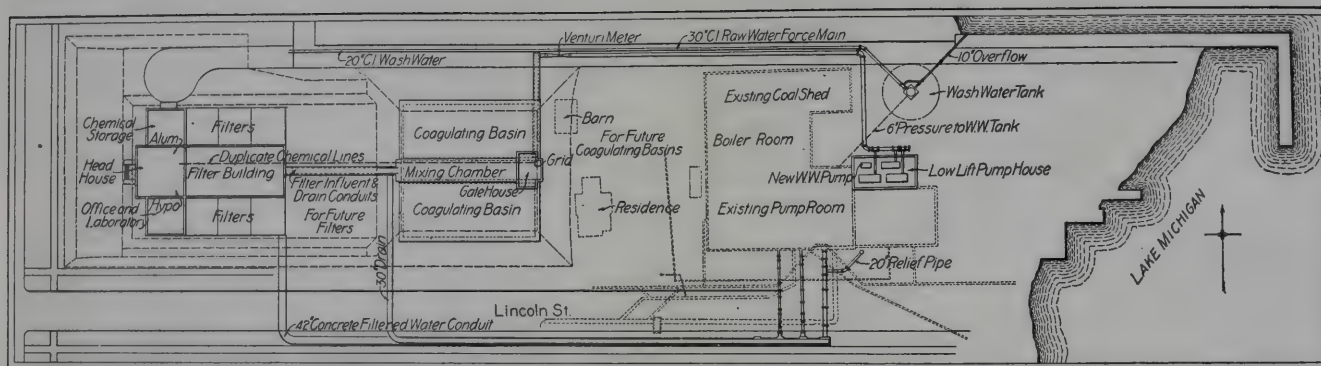


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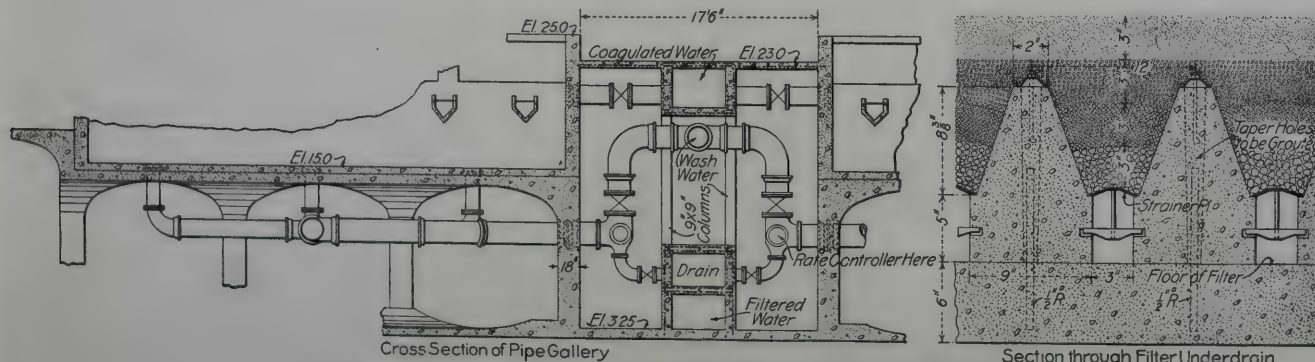


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Relation of Tanks, Filters and Mechanical Equipment of Evanston's Filter Plant.



Cross Section of Reservoir, Pipe Gallery and Underdrains, Evanston's Filter Plant.

erected behind the present pumping station on the lake front by the Chicago Bridge and Iron Works. It will be fed by a bleeder from the present high service mains. Fluctuations in the pressure due to the drop of level in the wash-water tank will be taken care of by a controller to be placed in the line at the entrance to the filter gallery. (See Plate VIII.)

The work is being carried on under a general contract with the Norwood Engineering Company, Florence, Mass., the concrete work, head house, and excavation being sub-let to the Macdonald Engineering Company, Mr. James Macdonald (M. W. S. E.), President. Owing to the situation, it was impossible to bring material in other than by team, a haul of approximately one mile being re-



Fig. 21.—Steel Screed for Inverted Groined Arches.

quired from the nearest railroad switch. The contractor, therefore, has developed a plant for the elevating and storage of the gravel and sand in bins to minimize the handling by hand. The teams dump into a hopper from which a belt conveyor delivers the material to the sand or gravel bins. Storage sheds for cement are built alongside the bins. A Ransome concrete mixer discharges into two-wheeled buggies on an elevator for raising or lowering the cars of concrete to the appropriate level for placing. One inch yellow pine flooring has been used for form work wherever possible, with 2 by 4 in. studs spaced about 16 in. on centers tied with very heavy wire.

The inverted groined-arch column bases were formed up continuously in rows by the use of a "spider," a metal frame consisting of 1-in. angles making a square, from each corner of which malleable castings of the shape of the groin converged to the base at the center, where they were held together by plates. In use, the

angle frame was set on the two 6-in. floor form strips and held there by pins. After running a cut-off strip over each pair of legs and getting the base shaped, the form was removed to the adjoining base and the corners smoothed up.

The groined-arch forms for the roof have been built in a manner different from that usually employed on such work. The form units are framed in the carpenter shop and transported to place on a pair of wheels. They fill the squares between the column corners, leaving a width approximately that of the column to be filled on the job, with short pieces of 1 in. flooring nailed in place by carpenters.

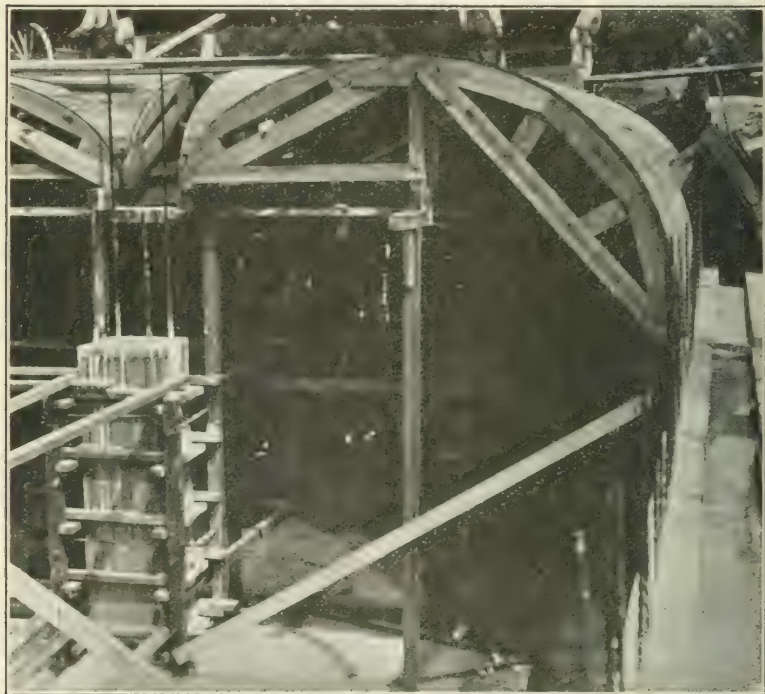


Fig. 22.—Forms for Groined and Barrel Arches.

This method was feasible because of the short span. The groined-arch forms were carried on stringers resting on the vertical tie studs of the column forms. The forms have been stripped at a minimum time of five to seven days, ten days being secured wherever possible. For the construction of the 30 in. wash-water drain and 42 in. filtered-water conduit, suitable circular collapsible forms were built of wood. At the bends a built-up form has been used, made of laths, plastered smooth with ivory wood-fiber plaster, smoothed up

with paraffine wax dissolved in kerosene. The forms were destroyed before removal.

The excavation has been made on all the mass work with a Thew shovel, loading two-horse bottom-dump wagons with which the spoil was carried to adjoining lots or dumped on the lake front. The earth was fairly stiff, so that no sheeting was required except in trenches left open for days. The upper 5 ft. of excavation was loam and sand containing some water, under which a clay stratum was found, free from water. Some of the sand from the excavation was suitable for use in the concrete, but the major portion of the concrete was made with torpedo sand and gravel brought from pits along the Fox River. The imported sand was found somewhat unsuitable, owing to the lack of fine material, so that a mixture was

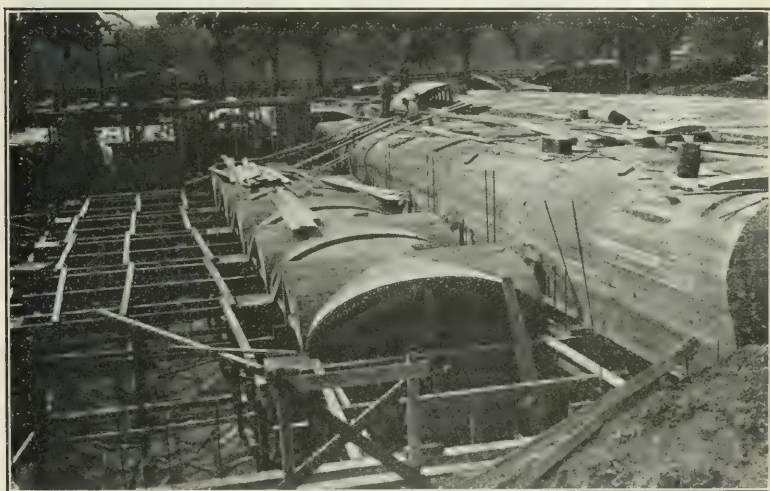


Fig. 23.—Adjustment Space Between Groined Arch Forms.

made of one part plastering sand and five parts torpedo sand for general use. This made a nicely-working tight concrete.

At present the work has progressed through the completion of the filtered water basin. Two of the filters and the head house are in process of erection, and the coagulating basin is well under way. It is the intention to have the work under cover for the winter, so that it can be completed by the contract time, next spring, May 31, 1914.

In conclusion, I wish to acknowledge the courteous assistance and cooperation of Mr. J. H. Moore, Commissioner of Public Works, and the continued interest of Mr. M. O. Kasson, Superintendent for the Macdonald Engineering Co.

James Macdonald, M. W. S. E.: We are using a new method

for forming concrete, under certain conditions. The scheme is a little different from the ordinary construction, and is what we call a moving form. It consists of a wooden mould made to represent the work that is to be built. The walls are inclosed in a wooden frame structure with which it is spanned, and a suitable jack mechanism, having a U-shaped yoke, is provided, which spaces the faces of the walls that are filled with concrete. The jack is supported by $1\frac{1}{8}$ in. vertical rods from the foundation, and these rods are continuous from the top to the bottom. The whole mechanism is carried by the jacks so that the concrete supports nothing but itself during construction. The weight of the form, and the steel work which is going into the form, also of the men and material, is not carried on the concrete which we are moulding. In starting, we

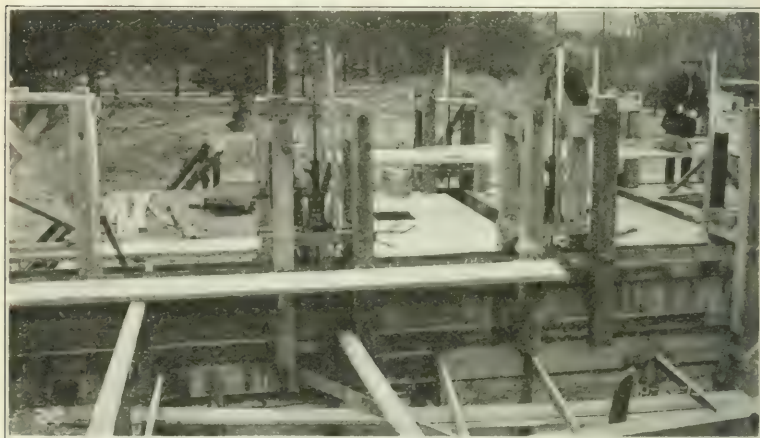


Fig. 24.—Movable Forms for Reinforced Concrete Walls.

deposit a small amount of concrete in the form, and this is allowed to stand until it is partly set. The concrete that is first deposited is uncovered inside of three or four hours by jacking the form upwards. The whole form is then raised with the jacking mechanism, the men standing on top of it. The lifting movement amounts to only about $\frac{1}{4}$ in. at a time, and the form is continually filled and kept in motion. The work goes on day and night, and we build from 8 to 10 ft. in height of the wall in 24 hours, depending upon the temperature of the air. The form is about 3 ft. 6 in. to 4 ft. high.

This method is employed mostly in the construction of grain bins or similar containers, and wherever we have a compartment to build which admits of using parallel vertical walls. At the present time we propose to use the method in connection with some thin walls that are to be built, instead of using plaster and expanded metal. The panel walls are to be 2 in. thick and 12 ft. high, and it

would be difficult to plaster them in the ordinary way. We propose to build the walls with moving forms, reinforce them with rods in the usual way, placing the rods in the walls as the form moves up. We shall build the chemical tanks in the same way, and are just now starting that part of the work.

Mr. Hansen: I will ask Mr. Macdonald how he splices the vertical rods that are used to support the weight?

Mr. Macdonald: The mechanism which we use has a pump-handle apparatus which grips the vertical rod concentrically, so that the load is carried in the center of the rod. As stated, we use $1\frac{1}{8}$ in. rod, doweled together, and a $\frac{1}{2}$ in. dowel. When the grip is passing that, it does it very easily and has no distortion, no side motion, so that the concrete holds the lower rod securely as it is setting up, and the incoming rod, of course, passing through the jack, is free to come down and the mechanism clamps that way.

L. K. Sherman, M. W. S. E.: Do you have to make the concrete any drier than is ordinarily the custom?

Mr. Macdonald: On the contrary, we are making it as wet as we can use it.

Mr. Pearse: We found on analysis that there is not enough fine sand in the torpedo sand that we get commercially, and we are adding about one part of plastering sand to five parts of torpedo sand, in order to get the proper grade of sand for watertight concrete. We are not putting in any waterproof material at all, and are relying on the ingredients of the concrete. We were pursued, in the beginning of the work, by every waterproofing representative in town, who wanted his particular process specified.

It would seem that some study ought to be given in this particular region to the grading of materials. Study is not given, as near as I can find, anywhere in the city, to secure the degree of precision attained in large cities in the East and other parts of the country where they have had to build waterproof work. I refer particularly to work in connection with filter plants and the like, where they are building tanks 15 or 20 ft. high which must stand water pressure and not seep into a room that is used for working purposes. One part plastering sand to five parts torpedo sand is, as near as I can find, the way nature mixes it in the pits, but it is not the way it is usually specified.

The concrete mixture, if it is thin, is 1:2:4, and the mass work,—that is, the filter-water basin walls, floors and the like,—is 1:2½:5.

Frank L. Stone, M. W. S. E.: I have been interested in the Rock Island situation. I lived there for several years and am familiar with the plant, its development and treatment. The Mississippi water presents a problem which is very difficult to solve. The resultant water even today is very far from being what is desirable. In my opinion there is another reason for the considerable decrease of typhoid there, and that is that many of the inhabitants of that city are using artesian water for drinking purposes, and are not

using the filtered river water. I visit Rock Island several times a year, and do not recall having had a drink of the Rock Island municipal water within the last ten years that was really fit to drink. It may be *safe*, but it is not palatable or nice. I do not wish to be misunderstood, as I appreciate fully the safety and advantage to a community resulting from a properly treated water supply.

I desire only to bring to the attention of engineers the necessity of locating troubles which may be found outside of the laboratory. In my opinion one of the principal troubles is the lack of or insufficient cleaning of the mains.

W. W. DeBerard, M. W. S. E.: Very little has been said tonight about operation. In my estimation, the operation of a plant ought to be emphasized as much as possible. What we build a purification plant for is to get something out of it that we can drink, use, put on the table and be proud of. If Mr. Stone cannot drink the water when he goes to Rock Island because of temporary lapses in operation, that plant, as far as he is concerned, is a failure. Undoubtedly the Evanston plant is the forerunner of filtration for the whole of Chicago. That subject has been broached in more than one meeting in Chicago, and it is reasonable to predict that within ten years' time we will be getting water that is not only pure from the bacterial standpoint, but which has no turbidity which one can see through an ordinary drinking glass.

Downtown in Chicago the water is not always clean. Tonight at supper at a restaurant the water on the table had a turbidity of between ten and twenty, and I do not think we are going to stand that very long. Within ten years' time I look for filters to be built in the city of Chicago, and it is none too early to begin thinking and talking about them.

*L. A. Jahn*s (Commissioner of Public Properties, Moline, Ill.): I should like to have the author bring out the points that were mentioned in the discussion as to the relative size of the hypo and alum solution tanks. In one of the illustrations they appear to be of nearly uniform size. Is that best or necessary? I have heard that this arrangement has been adopted in some cities; the use of the tanks is alternated so that the action of the alum on the iron pipe may not be so severe. The hypo produces a coating there which the alum in time will remove, and vice versa.

I did not quite understand the nature of what I think the author calls the mixing chamber or reaction chamber; is it to produce a more complete and thorough mixing of the alum solution with the raw water? Could that mixing be accomplished by introducing the solution into the suction end of the usual low-lift pump device for lifting the water, getting the benefit of the agitation which the pump would give it? Also, as in our lay-out, if the solution were introduced right into the raw water suction pit or well, would that overcome the necessity for the reaction chamber construction where it has not been provided for in the original plan?

Dr. Bartow: The reaction chamber is especially valuable where lime is used. If lime should be introduced at the suction end of a pump it would so incrust the working parts of the pump that it would put it out of commission. A reaction chamber is made large enough to be readily cleaned and yet small enough to give a rapid flow and thorough mixing of the water with the coagulant, not so much with alum as with lime.

The relative size of the hypo and alum solution tanks is an arbitrary matter to be settled in accordance with the local situation. If a larger amount of alum must be used, the tank must necessarily be larger. Furthermore, the larger the hypo tank the less frequently must it be filled. It is, I think, a matter of choice.

Frank W. DeWolf, M. W. S. E.: I have nothing to add to the discussion on the paper of the evening, but I would like to ask your indulgence while I bring up another matter, which is somewhat related, for the reason that I think some of the members present will be interested and will be in position to assist in a new investigation of deep-well waters which is about to begin.

Dr. Bartow showed on the first map of the state that in the northern region there is considerable use of deep-rock wells. The Geological Survey, in cooperation with the Water Survey, is about to study the water resources of those deep beds, beginning in the Chicago region. We are told that during the last ten or fifteen years the head of artesian water in the Chicago area has been lowered something like 150 ft., and this fact is of considerable concern to those large commercial plants which use artesian water.

We are about to begin a systematic study of all the data which we can get throughout the state. We are interested in the geology of the beds, the quantity of the water, its rapidity of movement, the capacity of deep wells, their effect on neighboring wells, their ability to "come back" after severe usage, and in other matters of that sort. We particularly want to get information on the wells in this Chicago region. We should like to have the help of each man here who has any professional knowledge of the location of deep wells in this northern part of the state, and who has any data of any sort,—well records, pumping records, analyses of the water,—so we can get this work started as quickly as possible without overlooking any important data.

Mr. Anderson, of the Survey, will be in charge of our part of the work, and the Water Survey will make its investigations at a little later date. Either Mr. Anderson or myself would be glad at the close of this meeting to get the names of any members here who may have anything to offer us, so that at some convenient date we can call, if desired. If it is impossible to obtain the names this evening I would request of any one who can help us that you send your name to the office of the Survey at Urbana, and indicate a convenient time for a conference.

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Regular Meeting, December 1, 1913.

A regular meeting of the Society (No. 839) was held December 1, 1913. The meeting was called to order at 8:30 p. m. by President Reichmann and with about sixty-five members and guests in attendance.

The minutes of the last regular meeting, held November 3, 1913, were read and approved. The Secretary reported from the Board of Direction that at a meeting held that afternoon the following had been elected into the Society:

John A. Goetz, Arcola, Ill.....	Affiliated Member
Alfred Luebeck, Chicago.....	Associate Member
Thomas A. Banning, Jr., Chicago.....	Junior Member
A. Edwin Sackerson, Chicago.....	Junior Member
Joseph E. Love, Chicago.....	Junior Member
Eleuterio Martinez, Jr., Mexico City, Mex.....	Junior Member
Joseph F. Ward, Evanston, Ill.....	Student Member

Also that the following had applied for admission or transfer:

William M. Willett, Aurora, Ill.
William F. Jordan, Chicago, transfer
Arthur B. Shenk, Evanston, Ill.
Wilhelm C. Reith, Montreal, Can., transfer.
Perry C. Mark, Zanesville, Ohio, transfer.
Albert J. Schafmayer, Chicago, transfer.
Frank H. Pond, Chicago.
Balthasar Hoffman, Chicago.
Ralph A. Bennett, Chicago, transfer.
David J. Johnson, Chicago, transfer.

The Secretary also reported the result of canvass of petitions for nominations for officers of the Society for the new year:

For President—Messrs. A. Bement, T. L. Condron, William B. Jackson and E. H. Lee.

For First Vice President—Messrs. B. E. Grant, E. N. Layfield and W. H. Pratt.

For Second Vice President—Messrs. H. J. Burt, F. W. Dencer, Ernest McCullough and I. F. Stern.

For Third Vice President—Professors O. H. Basquin and G. F. Gebhardt.

For Treasurer—Mr. C. R. Dart.

For Trustee (to serve three years)—Messrs. H. S. Baker and C. D. Hill.

There being no other business before the Society, the President introduced Mr. J. W. Pearl, M. W. S. E., who read his paper on "Retaining Walls." Discussion followed from Messrs. W. C. Armstrong, O. P. Chamberlain, Ernest McCullough, C. R. Dart, B. E. Grant, E. E. R. Tratman, J. F. Hayford, A. C. Warren, S. T. Corey, W. S. Lacher, F. G. Vent, I. F. Stern, with replies and blackboard explanations from Mr. Pearl.

Meeting adjourned at 10:30 p. m.

Extra Meeting, December 8, 1913.

An extra meeting of the Society (No. 840) was held Monday evening, December 8, 1913, in the interests of the Bridge and Structural Section. The meeting was called to order at 8:15 p. m. by J. H. Prior, Vice Chairman, with about ninety members and guests in attendance. The minutes

of the preceding meeting of this Section were not read, but were approved as published. The Chairman announced that in accordance with the Rules of the Section, nominations were in order for members of the Executive Committee, the same to be voted on at the next meeting of the Section, to be held in January, 1914. The nominations made were:

For Chairman—J. H. Prior.

For Vice Chairman—J. W. Musham.

For Directors (two to be elected)—E. N. Layfield, O. H. Dalstrom and H. C. Lothholz.

Prof. Albert Smith, M. W. S. E., of Purdue University, Lafayette, Ind., was then introduced, who presented his paper, "Wind Loads on Buildings." This was illustrated with some lantern slide views. Discussion followed from Messrs. J. W. Pearl, Andrews Allen, E. A. Howes and E. N. Layfield, with replies and explanations from Professor Smith. Mr. N. M. Stineman moved a vote of thanks to Professor Smith, which was carried.

Meeting adjourned about 10 p. m.

Extra Meeting, December 15, 1913.

An extra meeting of the Society (No. 841) was held Monday evening, December 15, 1913. The meeting was called to order by Trustee F. E. Davidson at 8:30 p. m., with about sixty-five members and guests in attendance. The Chairman introduced Mr. Meyer J. Sturm, M. W. S. E., who read his paper on "Ventilation." Discussion followed from Messrs. J. W. Shepherd, H. J. Thorkelson, William B. Jackson, F. E. Davidson, A. Scheible, E. N. Layfield, H. Gansslen, W. W. De Berard, F. J. Postel, J. R. Cravath and Ernest McCullough, with replies and explanations from Mr. Sturm.

Meeting adjourned about 10:45 p. m.

Extra Meeting, December 17, 1913.

A special extra meeting of the Society (No. 842) was held Wednesday evening, December 17, 1913. The meeting was called to order at 8:30 p. m. by Trustee F. E. Davidson, who, after a few words of explanation and greeting, introduced Mr. Franklin H. Wentworth of Boston, Secretary of the National Fire Protection Association. Mr. Wentworth addressed the meeting on "A Campaign to Prevent Fire." Discussion followed from Messrs. J. C. McDonnell, of the Fire Prevention Bureau; F. D. Chase, W. C. Robinson, W. G. Uffendell, F. E. Davidson and Ernest McCullough.

In conclusion, Mr. E. N. Layfield offered a vote of thanks to Mr. Wentworth for his instructive and entertaining address.

Meeting adjourned at 10:30 p. m. There were about forty members and guests in attendance.

J. H. WARDER, Secretary.

BOOK REVIEWS

The Books Reviewed Are in the Library of This Society.

LABORATORY MANUAL OF TESTING MATERIALS. By Prof. W. K. Hatt, M. W. S. E., and H. H. Scofield, M. E., Purdue University, Lafayette, Ind. 135 pages; 5 by 7½ in.; illustrated; cloth bound. Price, \$1.25. McGraw-Hill Book Co., New York, 1913.

This book is especially of service to students of inspection and testing of materials of construction. The student is drilled in the preparation of reports of tests made, the drawing of diagrams exhibiting the behavior of a test specimen when under test, and which thus exhibits the physical characteristics of the material tested. In Chapter III is given various definitions, which are a necessary preliminary to the understanding of instructions which

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followed. The Stress of Materials beyond the elastic limit is the subject of Chapter IV, while Chapter V contains a list of large testing machines, and the main characteristics of each, also illustrations of manner of making tests, whether tension, compression, shearing, or impact; also, the weighing mechanism, extensometers, and the like. As part of a text book for laboratory use, are Chapters VI, experiments, and VII instructions for performing experiments,—which include that of hydraulic cement, and the aggregate. The latter part of this chapter relating to cement and paving material is very useful and complete.

The Appendix contains a number of formulas relating to tension and compression tests, impact tests, abrasion tests, etc. Also strength of steel and iron and the standard specifications for cement as recommended by the American Society for Testing Materials.

The book is well written and illustrated, and is well worth the attention of students of engineering.

THE STOCK EXCHANGE FROM WITHIN. By W. C. Van Antwerp. Doubleday, Page & Company, New York, 1913. Cloth; 5 by 7½ in.; 459 pages, including index; illustrated.

The author's preface is as follows: "In so far as these pages reflect the thoughts of a busy stockbroker, distracted by many duties and lacking in literary skill, they have but little merit and the writer entertains no illusions regarding them. But in the many quotations from the writings of the world's foremost economists that are here presented, and in the various legal and historical precedents cited, perhaps it is not too much to hope that this book possesses some slight value as a contribution to the vexed and vexing discussion of the Stock Exchange, and that it may serve in some degree both to dull the sharp edge of uninformed criticism and to strengthen the hands and hearts of loyal friends of a greatly misunderstood institution. The public is asked to disregard the utterances of demagogues and self-seekers and to consider facts. That done, the American spirit of fair play may be confidently relied upon.

"The Stock Exchange authorities have had no hand in the preparation of the work, nor does it bear their endorsement. I say this lest it be thought an official *apologia*. Had it been such, the work would have been much more skilfully done, and its value greatly enhanced."

There are ten chapters, as follows: I, The Functions of the Stock Exchange. II, The Uses and Abuses of Speculation. III, The Bear and Short Selling. IV, The Relationship Between the Banks and the Stock Exchange. V, Publicity in Exchange Affairs: Cautions and Precautions. VI, Panics, and the Crisis of 1907. VII, A Brief History of Legislative Attempts to Restrain or Suppress Speculation. VIII, The Day on 'Change, with Suggestions for Beginners. IX, The London Stock Exchange, and Comparisons with Its New York Prototype. X, The Paris Bourse; A Monopoly Under Government. Appendix, The Report of the Hughes Commission.

The paper and type are excellent.

MECHANICS AND HEAT—An Elementary Course of Applied Physics. By J. Duncan. Macmillan & Co., Ltd., London, 1913. Cloth; 4¾ by 7¾ in.; pp. 381, including index and tables; with 314 text illustrations. Price \$1.

A very desirable book for study in an elementary course of mechanics and heat. There is an introductory chapter, pertaining to measuring instruments and their use, mensuration of areas and angles, and instructions for carrying out laboratory work.

Chapter II treats of Matter, Force and Weight, with examples of practical work. There are two pages of exercises following this chapter, which include a variety of problems. The next chapter treats of Forces Acting at a Point, and in Chapter IV is presented Moments, Parallel Forces and Center of Gravity, with various illustrations and examples, to be worked out by the student. This is followed by Stress, Strain, Elasticity and Ultimate

Strength, as the topics of Chapter V, which is presented in a clear and logical manner. In Chapter VI is presented Strength and Stiffness of Beams and Shafts. This includes the action of spiral springs, and is followed by a page of exercises.

Chapter VII is on Work, Velocity Ratio of Machines, Energy, Power Efficiency and Friction, with experiments and further exercises. Simple Mechanisms is the subject of Chapter VIII, with explanations on belts, gearing, the screw, pulleys, etc., and with exercises (an illustration), while in Chapter IX is treated the subjects of Velocity, Acceleration, Inertia, Kinetic Energy, Relative Velocity, Momentum, etc.

In Chapter X are presented the subjects of Hydraulics, Water Pressure, Floating Bodies and Specific Gravity.

Chapter XI concludes Part I, Mechanics, by treating of Hydraulic Machines.

The Second Part of the book relates to Heat, with chapters on Temperature, Expansion, Measurement of Heat, Properties of Gases and of Steam, and applications of the same.

In Chapter XVIII the subject is Fuels, of some seventeen pages, and followed by chapters on the Steam Engine, Boilers, efficiency of the same, and finally Internal Combustion Engines. There are various tables included in the book and exercises on the text for the benefit of the student are numerous, and appear to be well selected.

For an elementary work the arrangement of the topics, the illustrations and examples, and the exercises, appear to be excellent and worthy of commendation.

CONSERVATION OF WATER, by Walter McCulloh, C. E. Yale University Press, New Haven, Connecticut. 99 pp. 7 by 10 in. and 40 full page illustrations. Cloth-bound. Price \$2.00 net.

This book contains the addresses of Chester S. Lyman lecture series, 1912, before the Senior Class of the Sheffield Scientific School, Yale University. It is the first of the series of memorial lectures at the Sheffield Scientific School, on Water Storage Conservation.

The book opens with an Introductory, which is well written and is followed in Chapter II, relating to Basic Data essential to a comprehensive study of water storage. Water Power is the subject of Chapter III, and the next chapter considers Water Storage for Water Supplies, Sanitation and Irrigation. The final chapter (V) describes the Water Resources of New York State. There are 39 illustrations, diagrams, line engravings and half-tones, which increase the interest and value of the text.

The Water Power of Niagara Falls is known, in at least a general way, to almost everybody, but is set forth in some detail with illustrations in this book. But there are many other water powers in New York State, some of which have been developed, but only to the amount of about one-half of that available.

The author advocates the greater use of storage reservoirs to help maintain a more uniform flow of water in the streams and the conservation of the Water Powers, for industrial purposes.

The makeup of the book is commendable, in paper, typography, and binding.

HYDRAULIC TURBINES, with a chapter on Centrifugal Pumps, by R. L. Dougherty, of Sibley College, Cornell University, Ithaca, N. Y. McGraw-Hill Book Co., New York, 1913. 156 pages (including index), 6 by 9 in. with 96 illustrative diagrams, and half-tone engravings. Cloth bound. Price \$2.00 net.

A generation or so ago, there were evolved out of the inner consciousness of some ingenious mechanics various forms of hydraulic motors or turbines. As originally built, the term *designed* could hardly be applied, for the shape of the guides and vanes, of the runner and of the gates, was largely

guessed at, and tried out experimentally. The results claimed for such machines by the inventor, were frequently very extravagant and unfounded. But in those days a knowledge of the energy of the water used, by which to determine the efficiency of the water wheel, was generally lacking. The foundryman making the turbine sometimes got good results in some special location, and everybody was happy. Nowadays more exact and scientific principles are demanded, and a knowledge of the basic elements should be possessed by those concerned in this class of engineering work, so that the consulting engineer may make a more intelligent selection of the type and size of turbine, for any special set of conditions. It is for this class of engineers that this book has been written, but it may prove of interest and value to others in the profession. The broad and general problem of the development of water power is treated in such a manner that the reader may understand the conditions most closely related to the selection of a turbine water-wheel, but the very important problems of determining the available water power of a given stream, including rainfall, runoff, stream gauging, etc., is treated but briefly, as these matters have been considered more fully in other books.

The author of this book desires to give a general and comprehensive view of water power development, and the conditions affecting the operations of turbine water-wheels, also information of the general features of constructions, an outline of the characteristics and theory of the principal types of turbine water-wheels, means of selection, of type and size of the wheel, and its cost, as part of the cost of a water power and also a comparison with the cost of steam power.

As a natural sequence to a consideration of a rotating machine which yields energy, from a passing stream of water, is the converse, to impart impulse or energy to a stream of water by applying power to a rotating machine, as a centrifugal pump. A portion of this book is devoted to the subject of Centrifugal Pumps.

The book is worthy the attention of engineers.

LOCOMOTIVE BOILER CONSTRUCTION. By Frank B. Kleinbans, with additions by Geo. L. Fowler. Norman W. Henley Publishing Company, New York, 1913. 2nd ed. revised, 462 pp.; 8x5½ in.; cloth; fully illustrated with detailed engravings and folding plates. Price \$3.00.

A handsome, neatly printed, well bound volume. The author in his preface attaches considerable dignity to the locomotive type of boiler, claiming, and rightly, that an engineer or foreman who can correctly lay out a locomotive boiler will have no difficulty in handling any other type of boiler.

The book is divided into a number of sub-heads or grand divisions, but some are not given the dignity of chapters, nor are they indexed. It would have aided in reference study had they been so designated.

The illustrations, and there are many of them, are excellent examples of line work, and add much to the value of the book. This is true of the construction diagram and of the special tools that are shown in the engravings. The author expresses a decided preference for iron over steel rivets.

The book is also interesting and valuable as a reference, to the engineer who handles boiler problems only occasionally. Numerous tables are given to aid the layer-out in his work.

Table No. 6, on Properties of Saturated Steam, is an old one adapted from Haswell, and does not agree with recent practice.

Tables Nos. 5 and 6 are not numbered and one or two minor typographical mistakes occur in the volume.

On the whole the book is a valuable addition to engineering literature and is clearly written.

ALTERNATING CURRENTS AND ALTERNATING CURRENT MACHINERY. By D. C. and J. P. JACKSON. New edition, rewritten and enlarged. The Macmillan Co., New York, 1913. Cloth; 5½ by 9; 968 pages, including index; over 500 diagrams, curves and illustrations. Price, \$5.50.

This book is splendidly written as a text-book for students in advanced electrical engineering, as well as a reference book for engineers on alternating currents.

Starting with fundamental principles and the formulas governing alternating current phenomena, the authors build up complete machines. They then review the various graphical and analytical methods for determining the characteristics of these machines, and by their application, derive these characteristics, show the effect of modifications in design on the characteristics, and show the limitations beyond which these modifications cannot be carried without sacrificing other more important features of design.

Following this development, the authors describe the latest practices in the design and testing of alternating current machinery, and give a brief description of different types of alternating current machinery that has come into general use.

The illustrations are, for the most part, of strictly modern machines. Much of the late subject matter is drawn from recent papers delivered before the American Institute of Electrical Engineers. These and other characteristics reflecting the authors' wide acquaintance with the latest developments and practices in alternating current engineering, make this book valuable to the student and the engineer.

Following is a brief resumé of each of the thirteen chapters:

Chapter 1 briefly reviews the fundamental conception of the alternating waves of current and e. m. f., the various analytical and graphical methods of their solution, the method of applying the underlying principles in the design of alternating current generators, and the effect on wave form of changes in the details of design of these generators.

Chapter 2 shows how the properties of the alternating wave are utilized in transformers and measuring instruments.

Chapter 3 covers the different methods of winding and connecting A. C. generators and discusses the properties of the materials entering into their construction.

Chapter 4 treats of self-inductance, capacity, reactance and impedance and the effects of combinations of these properties.

Chapter 5 covers in considerable detail the subject of complex quantities.

Chapter 6 discusses and applies graphical and analytical analysis to series and parallel circuits containing resistance, inductance and capacity.

Chapter 7 treats of power factor and the analysis of circuits in which there exists a phase displacement between current and voltage and discusses the methods of measuring and errors in the measurement of A. C. power.

Chapter 8 covers the systems of connection, the vector relations of quantities in circuit and measurement of power in polyphase systems.

Chapter 9 discusses the magnetic circuit, losses in this circuit by hysteresis and eddy currents, the measurement of these losses and their effect on the wave form of the exciting current.

Chapter 10 is a discussion of mutual inductance as applied to transformers. The methods of analysis by vector diagrams and questions of magnetic leakage, exciting current, hysteresis and eddy currents, wave form, efficiencies and losses are discussed at length. This is followed by a discussion of details of construction of transformers, errors in connection, three-phase transformers and transformation between three-phase and two-phase. Some comment is given to current transformers, reactance coils and compensators.

Chapters 11 and 12 treat in a similar manner the design and characteristics of synchronous machines and asynchronous machines, respectively, and contain some comment on the T. A. regulator, feeder regulators and oil switches. These chapters also discuss questions of hunting and division of load between alternators in parallel, the use of the synchronous condenser and latest methods of testing these machines.

Chapter 13 is a chapter on skin effect, self and mutual induction and capacity of parallel conductors and losses by corona.

Great credit is due the authors for the comprehensive way in which they have covered this broad subject, setting before the reader the last word in this line of engineering.

J. L.

OVERHEAD ELECTRIC POWER TRANSMISSION. By Alfred Still. McGraw Hill Book Company, Inc., New York. 1913. Cloth; 9¼ by 6 in.; pp. 310, including index; illustrated. Price, \$3.

This volume deals with the theoretical calculations and economic considerations affecting the design of overhead transmission lines, and will be of value to students and engineers having such problems to solve. It supplements the book on "Transmission Line Construction," by R. A. Lundquist, the two making a very useful and concise treatment of Overhead Transmission Line Work.

The formulæ for the selection of most economical voltage, size of conductor, voltage drop and other factors affecting overhead lines are arranged in convenient and simple form. The constants for copper, aluminum, steel, copper clad and stranded cables are also conveniently arranged in tables. It may be questioned whether some of the formulæ would not be more workable if power were expressed in kilowatts instead of in horsepower.

The use of the Mershon diagram and the effect of capacity on line drop are fully set forth. Insulators, lightning arresters, corona effect and allied phenomena are appropriately grouped in the fifth chapter.

There is a chapter on mechanical design which treats clearly the effects of wind pressure and temperatures on tension and sag. This is followed by a chapter on poles and towers, which is in such form as to enable the young engineer to exercise judgment as to the selection of the type of supports with a very fair degree of intelligence. This chapter includes a considerable amount of data regarding concrete poles, which should be valuable in many situations.

Several appendices contain derivation of formulæ for inductance of circuits, transposition of wires and drop on three-wire, two-phase circuits. Others expand upon the methods determining the deflections on a flexible tower line and the stresses incident to tension in lines on a hillside. These are of considerable value, as it is more often the special problems of this kind which trouble the engineer than general problems.

The last two appendices are sample forms of specifications for line construction, one for poles and another for tower lines, which will be useful as reminders in drawing specifications for such work.

H. B. G.

THE IMPROVEMENT OF RIVERS. By B. F. Thomas and D. A. Watt. John Wiley & Sons, New York. 1913. 2d ed. Cloth, 11½ by 9 in.; pp. 749, including index; many illustrations, including 76 plates. Price, \$7.50.

The second edition, rewritten and enlarged, of "The Improvement of Rivers," by B. F. Thomas and D. A. Watt, United States principal assistant and United States assistant engineers, respectively, is a most timely publication and an improvement over the first edition, much of the tabulation and "primary engineering" of that edition having been omitted and more space given to general principles.

The control and regulation of our rivers is a matter that is forcing itself more and more upon the public mind, and while this publication is written supposedly from the viewpoint of "navigation," it has much matter and many drawings that can be applied to flood control and overflowed land protection, and for this reason Part I especially should be closely studied by the engineers of the country, who are interested in flood prevention and protection and in the reclamation of overwet lands.

The first chapter, "Characteristics of Rivers," is quite general, but plainly shows a personal knowledge that can only be acquired by experience "on

the job." Particular heed should be given to the paragraphs relating to "erosion," "caving" and "cutoffs," for here many an engineer finds unexpected troubles in his levee work and protection of banks, but in the chapters devoted to these two subjects he will find the much needed help.

The chapter on "reservoirs" is complete and interesting, and the facts are fairly stated. A perusal of the book is recommended, not only to the practicing engineer, but to the many laymen interested in such subjects, especially those who may be advocating flood protection by "levees only" or by "reservoirs only" or by any other one method. Such advocates should be thereby convinced that the problem is one of such difficulty and magnitude that after we have reforested our drainage area, formed our reservoirs, built our levees, revetted our banks, regulated our channels and improved the outlets, the floods will still keep us struggling to prevent loss of life and property.

E. T. P.

LIBRARY NOTES

The library committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts the following publications have been received:

NEW BOOKS.

McGraw-Hill Book Co.:

Compressed Air Practice, Frank Richards. Cloth.

The Macmillan Co.:

Descriptions of Land, R. W. Cautley. Cloth.

Industrial Chemistry, H. K. Benson. Cloth.

D. Van Nostrand Co.:

Suspension Bridges and Cantilevers, D. B. Steinman, 2d ed. Boards.

MISCELLANEOUS GIFTS.

Chicago Bureau of Public Efficiency:

Report on the Office of County Treasurer of Cook County. Pam.

John W. Alvord, M. W. S. E.:

Preliminary Copy of Summary and Estimates from the Report on Flood Protection for the City of Columbus, Ohio, Alvord & Burdick. Pam.

The Madison, Wis., Sewage and Disposal Plant. Pam.

John M. Sweeney, M. W. S. E.:

Pictorial History of the Los Angeles Viaduct. Pam.

G. B. Hegardt, M. W. S. E.:

History of the Mouth of the Columbia River. Pam.

Bion J. Arnold, M. W. S. E.:

Report on Railroad Terminals of the City of Chicago. Arnold, November, 1913. Cloth.

Illinois Secretary of State:

Illinois Public Utilities Commission Law. Pam.

D. A. Abrams:

Test of a 40 Foot Reinforced Concrete Bridge. Pam.

H. G. Tyrrell, M. W. S. E.:

The Esthetic Treatment of City Bridges, Tyrrell. Pam.

The Bridges of Cleveland, Tyrrell. Pam.

EXCHANGES.

Oklahoma Geological Survey:

Bulletin No. 11, The Gypsum and Salt of Oklahoma. Cloth.

Iowa Geological Survey:

Annotated Bibliography of Iowa Geology and Mining. Cloth.

American Society for Testing Materials:

Proceedings, 1913. Paper.

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